EARTH OBSERVING SYSTEM

HEARING

BEFORE THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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EARTH OBSERVING SYSTEM

TUESDAY, OCTOBER 2, 1990

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D. C.

The subcommittee met, pursuant to call, at 2:12 p.m., in Room 2325, Rayburn House Office Building, Hon. Bill Nelson [chairman of the subcommittee], presiding.

Mr. NELSON. Good afternoon. When I had the privilege of first coming to Congress 12 years ago, we had a host of public policy issues to deal with. And interestingly, global climate change was not on that list. But in the meantime, we have all become wiser, and now there is a widespread concern and beginning understanding that humanity has the profound ability to change the global environment. As a matter of fact, we get quite concerned if that might not be a change with catastrophic consequences. Now, there is widespread support here in the Congress for efforts to do all we can to collect the data that will help us better understand this global change.

So, today we are going to review the Earth Observing System, which is a major new science initiative for NASA. EOS is likely to have an increasingly significant impact on NASA's science and applications program.

There is widespread support here of the goals of the Mission to Plant Earth. It is intended to give decision-makers a better understanding of our Earth, of our Earth as a system and of the influences that will change our global environment. And yet there has been continuing controversy about the implementation approach chosen by NASA.

So the purpose of this hearing today is to examine some of the major issues surrounding the EOS program, and we're going to need to ask some tough questions.

Now, for example: What is EOS going to cost and what benefits will we receive for the investment?

Give you another example: Are there other approaches to space-based observation that would yield useful results other than EOS?

Another question: Are adequate resources being devoted to the data management system that will be the key to the ultimate success of this Global Research Program? Tremendous volumes of data that are going to be streaming in, something like the equivalent of what's stored in the Library of Congress, every few days.

Another question: What are the options if funding is not available for EOS and what are the options of that funding is constrained?

So these are the questions we're going to be asking, and we're looking forward to our panel of distinguished presenters today.

[The prepared opening statement of Mr. Nelson follows:]

OPENING STATEMENT
OF
THE HONORABLE BILL NELSON, CHAIRMAN
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OCTOBER 2, 1990

WHEN I FIRST CAME TO CONGRESS 12 YEARS AGO, WE HAD A HOST OF PUBLIC POLICY ISSUES TO DEAL WITH. GLOBAL CLIMATE CHANGE WAS NOT ON THAT LIST. IN THE INTERVENING YEARS, WE HAVE ALL BECOME WISER, AND THERE NOW IS WIDESPREAD UNDERSTANDING THAT HUMANITY HAS THE CAPACITY TO PROFOUNDLY ALTER THE GLOBAL ENVIRONMENT. INDEED, THE GLOBAL ENVIRONMENT AND THE POTENTIAL FOR CATASTROPHIC GLOBAL CHANGE IS PROBABLY THE TOP PUBLIC POLICY ISSUE IN THE WORLD AT PRESENT. IN CONGRESS, THERE IS WIDESPREAD SUPPORT FOR EFFORTS TO DO ALL WE CAN TO COLLECT NEEDED DATA THAT WILL HELP US BETTER UNDERSTAND GLOBAL CHANGE.

TODAY WE ARE GOING TO REVIEW THE EARTH OBSERVING SYSTEM (EOS), WHICH IS NASA'S MAJOR NEW SPACE SCIENCE INITIATIVE FOR FY91. EOS, IF APPROVED AND INITIATED, IS LIKELY TO HAVE AN INCREASINGLY SIGNIFICANT IMPACT ON NASA'S SCIENCE AND APPLICATIONS PROGRAM--AND ON NASA'S OVERALL ROLE AND DIRECTION--OVER THE COMING YEARS.

THERE IS WIDESPREAD SUPPORT FOR THE GOALS OF MISSION TO PLANET EARTH (OF WHICH EOS IS THE MAJOR COMPONENT): IT IS INTENDED TO GIVE DECISION MAKERS A BETTER UNDERSTANDING OF OUR EARTH AS A SYSTEM AND OF THOSE INFLUENCES THAT WILL CHANGE OUR GLOBAL CLIMATE.

HOWEVER, THERE HAS BEEN CONTINUING CONTROVERSY AND QUESTIONS RAISED ABOUT THE IMPLEMENTATION APPROACH CHOSEN, NAMELY THE EOS PROGRAM.

THE PURPOSE OF THIS HEARING IS TO EXAMINE SOME OF THE MAJOR ISSUES SURROUNDING THE EOS PROGRAM. BEFORE WE CONTINUE MUCH FURTHER INTO THE EOS PROGRAM IMPLEMENTATION, WE NEED TO ASK THE TOUGH QUESTIONS.

FOR EXAMPLE,

- O WHAT WILL THE EOS PROGRAM COST THE COUNTRY, AND WHAT BENEFITS WILL WE RECEIVE FOR OUR INVESTMENT?
- O ARE THERE OTHER APPROACHES TO SPACE-BASED OBSERVATION THAT WOULD YIELD USEFUL RESULTS EARLIER THAN EOS?
- O ARE ADEQUATE RESOURCES AND ATTENTION BEING DEVOTED TO THE DATA MANAGEMENT SYSTEM THAT WILL BE THE KEY TO THE ULTIMATE SUCCESS OF THE U.S. GLOBAL RESEARCH PROGRAM?
- O WHAT ARE OUR OPTIONS IF THE FUNDING AVAILABLE FOR EOS WILL BE CONSTRAINED OVER THE NEXT THREE YEARS AT LEAST?

THESE QUESTIONS ASSUME INCREASED IMPORTANCE IN THE WAKE OF THE BUDGET SUMMIT, WHICH WILL CAP DOMESTIC DISCRETIONARY FUNDING OVER THE NEXT THREE YEARS. WE WILL WANT TO EXPLORE THE OPTIONS FOR THE EOS PROGRAM UNDER THE LIKELY FUNDING CONSTRAINTS.

WE ARE HONORED TO HAVE DR. LENNARD FISK, ASSOCIATE ADMINISTRATOR OF THE OFFICE OF SPACE SCIENCE AND APPLICATIONS; DR. JOHN EDDY OF THE UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH; AND DR. WILLIAM BISHOP OF THE DESERT RESEARCH INSTITUTE JOIN US TODAY. THE LATTER TWO GENTLEMAN WILL BE PRESENTING THE FINDINGS AND RECOMMENDATIONS OF THE RECENTLY RELEASED REVIEW OF THE EOS PROGRAM PERFORMED BY THE NATIONAL RESEARCH COUNCIL.

NOW I WOULD LIKE TO TURN TO MR. SENSENBRENNER FOR HIS OPENING STATEMENT.

Mr. NELSON. Mr. Sensenbrenner?

Mr. SENSENBRENNER. Thank you, Mr. Chairman. The Earth Observing System (EOS) Program is a major new initiative in NASA's Fiscal Year 1991 Budget Request. The EOS concept and its ultimate goals are extremely popular and I support them. Our committee has already authorized full funding for this program in the NASA bill which passed the House last week.

Despite our support for the EOS concept, however, NASA has not necessarily convinced us, and others, that the currently proposed EOS architecture is the right way to go. The science community and others have raised several questions about the technical and scientific aspects of the EOS. We are fortunate to have appearing before our panel today two distinguished participants in the National Research Council's recent assessment of the EOS Program, and I look forward to a discussion of the Council's recommendations and criticisms, and NASA's response to them.

Mr. Chairman, it's also important that the EOS architecture reflect budget realities. Current cost estimates for EOS are in the neighborhood of $30 billion over the life of the program. I believe Congress and NASA have to seriously consider whether we can afford to make such a long-term commitment of funds before development of EOS proceeds too far. It may be necessary to scale back the EOS system NASA now envisions, which I think is kind of a top-of-the-line proposal, and it will be far more efficient to change plans sooner rather than later. During the course of today's hearings and future oversight activities we need to ascertain what less expensive options there are to EOS and what trade-offs would be if we pursued an alternative approach, and whether it is possible to do the same job at a lesser cost with different and less costly architecture.

Thank you very much.

[The prepared opening statement of Mr. Hall follows:]

OPENING STATEMENT OF CONGRESSMAN RALPH M. HALL
SSA SUBCOMMITTEE HEARING ON EOS
OCTOBER 2, 1990

Mr. Chairman, it is a pleasure to be here today to discuss the Earth Observing System (EOS). Not too long ago, our subcommittees held joint hearings on the EOS and had the opportunity to concentrate on the very important international aspect of this effort to study global change, and we had a productive session.

We have before us now a panel of witnesses that I am sure will provide us with an equally productive exchange, and I would like to thank you gentlemen for taking the time to be with us for what I hope will be a frank and informative discussion. Gentlemen, I will be asking some questions later that I put before the panel at our last joint hearing, and I look forward to getting some definitive answers on those.

The goals of this program are awesome, but so are the technical demands, as the National Research Council recently reported. Those findings justify the concerns I believe we all have regarding the EOS Data Information System (EOS-DIS). They also raise questions regarding the possibility of smaller satellites performing the science investigations assigned now to the EOS-B spacecraft. Also addressed in the review are the ever-present budgetary concerns that have permeated nearly every program in the NASA budget.

I know everyone in this room shares these concerns. We have, as a committee, committed ourselves to this project budgetarily, and now we must insure that commitment by working to find the way to most successfully implement the international goal of understanding natural and human-induced changes in the global Earth system.

Mr. NELSON. Okay. Now, we're going to do this in two panels. We're going to have Dr. Fisk, Associate Administrator. We'll ask you a few questions about, particularly, the funding aspects of it, and then we'll bring up the second panel and we might all join in together.

So, Dr. Fisk, if you would, don't read your statement. Just give us a summary and we can get right into a good dialogue.

STATEMENT OF DR. LENNARD A. FISK, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C. 20546

Dr. FISK. Okay. Thank you very much. It's a pleasure to be here, as always, to talk today about EOS. I have a statement and I'll submit it for the record. Perhaps I can just highlight a few things that, perhaps, are concerns to the committee that will start the dialogue with you.

I think you said very clearly and correctly in your opening statement what the tenets for doing this program are, the need to reduce the uncertainties associated with global change. Because we know that we are now influencing our global environment, we don't know how the Earth is going to respond, we're going to have to make policy decisions to both protect the environment and the economy and we need the best possible scientific basis for making those decisions.

Now, the President of the United States accordingly proposed in the fiscal '91 budget the initiation of the U.S. Global Change Research Program, which is a multi-agency effort involving agencies besides NASA, the National Science Foundation, NOAA, USGS, and so on. NASA's role in that, of course, is Mission to Planet Earth, of which EOS is the central part. We are to use our expertise in space exploration to provide these global observations.

Now, the program comes in four parts, and let me just remind you what those four parts are and tell you where we are with each one of them. The four parts are the—there are near-term missions which we are going to fly. Now there are some 19 or so of these missions. This includes things like the Upper Atmospheric Research Satellite, the TOPEX/POSEIDON to measure the surface of the oceans, there will be flights on the shuttle, and there is a series of Earth probes mission which are a small dedicated satellite measuring ozone, measuring ocean color (to do biological productivity of the oceans), and so on.

The purpose of those satellites is primarily to do process studies, individual processes, as to how the Earth works, and also to continue the monitoring of various key environmental parameters. They do not, however, provide the coordinated measurements of the Earth which is necessary to understand how the Earth is responding as a system.

If you ask yourself, "What do we need to know on the Earth in order to predict how it's going to respond to human influence", the principal things that's needed is what are the feedback mechanisms. If I put things in the atmosphere and I change the atmosphere composition with, say, greenhouse gases, what does the

Earth do? What is the response in the atmosphere? In the oceans? On the land? In the ice? And how are they coupled together? Because that is going to determine how the Earth responds to our human influence.

And, in order to do that, we have to have comprehensive measurements from the polar platform, which is what EOS is, two large polar platforms. Now, we are in the process at the moment—the platforms come in two parts; we call them EOS-A and EOS-B. EOS-A, we are in the final version of making the confirmation of the payloads. In fact, I earlier today was reviewing aspects of that. In another week or two we will confirm the payloads on EOS-A. EOS-B is to be confirmed at some later date. It doesn't really start till two years from now, and so we'll confirm that later on.

The EOS-A measurements are primarily measurements of the surface of the Earth, that includes the oceans and the land, surface of the Earth and atmospheric corrections that are needed to make those surface measurements. EOS-B is primarily to measure atmospheric chemistry and geodynamic. So the program sort of divides itself up into those two parts: EOS-A for the surface, EOS-B for the chemistry of the atmosphere and for geodynamics.

Now, this program has been one of the most—has been designed in a most interactive way with the science community. We have been thinking about this, working on this for at least the last 7 or 8 years. Literally thousands of scientists have been involved in the design of this program. It's been extensively reviewed by the Academy, by our internal committees, and so on. And the most recent review was, of course, the one you just mentioned, which is the NRC review by the U.S. Global Change Committee, and you have the chairman or representatives of those committees here today.

In a nutshell, the committee strongly endorsed the size and the plans for EOS-A, which is a fairly large platform, some 10 to 12 instruments measuring the surface of the Earth and its atmosphere corrections. They recognize, as we did, that there are certain instruments that need to fly together, that need to simultaneously look through the same column of air to make measurements of the Earth, and that determine the size of the platform, and I think that is pretty much a settled issue at this point.

In the case of EOS-B, which is the one that goes for atmospheric chemistry and for geodynamics, the committee said, "Think about dividing this up into, say, 3 smaller platforms," and we are in the process of thinking about that. There are two criteria that need to be applied.

The first criteria is the cost. We've pretty much convinced ourself that it won't cost less to do this, and the question is will it cost more? There are some arguments in favor of doing it for robustness for doing things, not doing all things on the same platform. But the question is can we afford to do that?

The second question is a pragmatic one: Can you launch it? These are polar orbit. In order to go into polar orbit, you launch out of the Western Test Range, Vandenberg. There are currently only 2 launch vehicles available out of WTR: there is a Titan IV and there is a Delta. We all agree that the Delta is too small; that you cannot put even some of the individual instruments on spacecraft that are small enough to fly in a Delta. So the question is can

a launch vehicle, say in the Atlas class, be made available out of the Western Test Range? Will the vehicle exist? Will the launch facilities exist? Who will pay for the launch facilities? Those are very pragmatic questions as to how to put this into space.

Now, fortunately, we have some time to figure this out. Because we don't begin the phase C/D, the actual development of the B platform, until fiscal '93, and so we have the next 2 years to sort out this question for doing so.

The third part of the system is the data and information system, which you mentioned in your earlier remarks. It has been a very active period for us in designing this, and I think you'll find that there is strong support for how we are doing this. It gets 60 percent of the money. It is the biggest single part of the EOS Program. That is an unusual thing for us to do. Normally in a science program we spend 70 percent of the money on space hardware and 30 percent of the money on that data system. This is the exact opposite: 40 percent on the space hardware, 60 percent on the data system on the ground.

It is a distributed system. Again, strong support for that. It is an evolving system. We recognize that over the 15 years, 20 years of this program, technology is going to change in data and information system. We have budgeted assuming that we will change out all the technology, all the data infrastructure, every 5 years as new technology comes along.

We need strong user involvement. We have a very strong user panel that is essentially designing the system with us. We recognize that we've got a learning experience here. We've never built a data system anywhere near this size, and so we have a very simple plan. Let's take existing data, some of which hasn't been adequately used, and let's use it in the '93 and '94 time frame, long before this platform flies, to test out the data system and have the added benefit of getting the scientific value out of that unused data. And we're going to do that and test out the system in the '93-94 time frame and have it fully operational when the EOS platform is launched.

The Request for Proposal (the RFP) for the prime contractor is set to go out in January or February of next year.

Finally, there is the issue of the science, the fourth part of the mission. All the observations we make, all the data that we generate is not going to be meaningful unless somebody turns it into understanding, and you can't assume that this is going to happen by chance. And so we have built into this program, into the funding for this program the scientists, support for the scientists who will actually turn this into understanding. There are 28 individual interdisciplinary investigations that—whose job is not to build instruments and not to turn those, the data into geophysical products, but to turn those geophysical products into understanding.

My guess is when those—that's fully operational, all 28 teams fully staffed, you're talking between 600 and 1,000 people who will be in the business of turning this into understanding.

We're also concerned about whose those people are. Are we educating the right number of people today who will, in fact, staff this program in the late 1990s, early 2000? So, again, the program includes funding for graduate students, fellowship programs, to train

those people who are going to be needed. We have recently selected some 37 graduate students in 1990. In 3 or 4 years we expect to be supporting 150 per year.

The program is as comprehensive as we know how to make it. We've put early missions in it. We've put the comprehensive observations in it. We've put an integrated data system in it. We put scienee in it. And we've put training of graduate students in it.

When somebody tells you there is a big price tag associated with this, there is. But please bear in mind that what you are seeing in this program today is everything that you will need. No hidden costs. Nothing we left out. Nothing we're going to come back later and say, "Gee. If you really want to do this right you're going to have to add." We tried in the beginning to tell you and everyone else what it was going to cost to do this thing. I will be happy to answer questions.

[The prepared statement of Dr. Fisk follows:]

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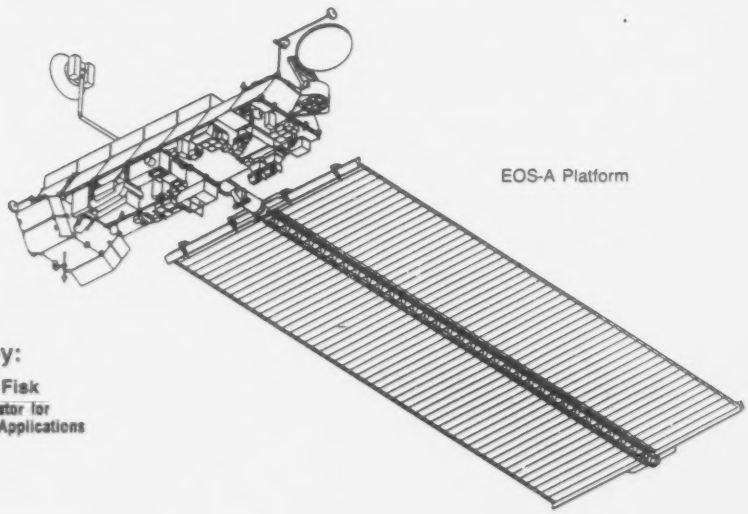
October 2, 1990

Subcommittee on Space Science and Applications

Committee on Science, Space and Technology

U. S. House of Representatives



EOS-A Platform

Statement by:

Dr. Lennard A. Fisk
Associate Administrator for Space Science and Applications

EARTH OBSERVING SYSTEM

101st Congress

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OCTOBER 2, 1990

Statement of
Dr. Lennard A. Fisk
Associate Administrator for
Space Science and Applications

National Aeronautics and Space Administration

before the

Subcommittee on Space, Science and Applications
Committee on Science, Space, and Technology
United States Senate

October 2, 1990

Mr. Chairman and Members of the Subcommittee:

I am very pleased to have the opportunity to appear before the subcommittee to discuss NASA's plans for a Mission to Planet Earth.

Mr. Chairman, we are at a unique point in human history. We know we are affecting the Earth's global environment, yet the outcome of these effects on the world are unknown. Some of these activities are dramatic. We burn the world's forests at the equivalent rate of one state of Tennessee per year. We load the Earth's atmosphere with carbon in the form of carbon dioxide, a known greenhouse gas, at the rate of five billion metric tons per year.

The planet we are affecting is also the most complicated in the solar system. It is the only one with oceans and life; and the interactions among the oceans and life, as well as the atmosphere, the land surface, and the ice, produce a very complicated set of mechanisms which control how the Earth behaves. And we are remarkably ignorant of how it all works.

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In essence, then, we are conducting a gigantic global experiment, the outcome of which is unknown. And since nature tends not always to work in our favor, we should be concerned that the outcome will not be favorable. Clearly, we cannot let this ignorance persist - we need to understand the Earth in a global sense, and we need to do so immediately. We need to understand how it works so that we can better assess how to effectively protect the future of the planet.

We need to recognize that because of these large uncertainties, it is difficult to know what actions should be taken. This is particularly true considering the significant economic and societal input associated with some suggested actions. A reduction in fossil fuel consumption, for example, by as little as 20% would have a dramatic impact on the world's economy. Clearly, we need an accurate scientific road map for how the Earth might respond to human activities so that we can chart a course which both protects our environment and our economy.

The President has proposed a comprehensive global change research program, the U.S. Global Change Research Program, to reduce the scientific uncertainties of pending global change. NASA's part of this program is to conduct the **Mission to Planet Earth**. This is not a traditional science program. This is not a program in which we are trying to incrementally increase our knowledge of the Earth. This is a crash program designed to rapidly expand our knowledge of the Earth so that we can provide the scientific basis for sound policy decisions.

As part of this program, NASA will launch some 19 Earth science missions over the next few years which will increase our knowledge of the Earth. We will construct a major data system that will come on line in the 1994 time frame to be able to incorporate the data from these upcoming missions (and from past missions) so that we learn as much as we can about the Earth and how it works. And we will double our support for basic research in Earth science.

But to understand sufficiently how the Earth works so that we can predict its future, we must develop an understanding of how the Earth works as a coupled system. Consider, for example, aspects of greenhouse warming. Carbon dioxide from industrial pollution is growing in the atmosphere and has the potential of increasing the temperature through greenhouse warming. However, the amount of carbon dioxide in the atmosphere depends on the amount absorbed by the Earth's biota. The response of the atmosphere to increased greenhouse warming may depend on whether there is a change in the cloud cover of the Earth, and at what altitude the clouds form. The response of the climate, in particular regional effects, will depend on changes in the global circulation of heat through the oceans. Indeed, the response of the Earth to human interactions will depend on the coupling and interactions which

occur among the various components of the Earth. These couplings generate feedback mechanisms that could either enhance or mitigate the effects of global change. The essential challenge to us, then, is to understand which feedback mechanisms are dominant, and how the Earth will respond.

The Earth science missions that will fly in the next few years will not yield definitive answers to how these coupling and feedback systems of the Earth work, and thus to how the Earth will respond to global change. In some cases the instruments that will fly have inadequate resolution and sensitivity. More important, they will not provide comprehensive observations of the components of the Earth at the same time. It is a simple reality that to understand how the oceans and the atmosphere and the biota interact and are coupled, it is necessary to observe the changes in these components, and the resulting responses in other components, at the same time.

To provide comprehensive observations of the Earth as a system, NASA will fly the **Earth Observing System**, or **EOS**. Two well-instrumented platform series in polar orbit, together with platform series from Europe and Japan, will provide long-term observations of the interactions among the components of the Earth, so that we can understand how the Earth works and project how it will respond to our continuing influence.

The cost of Mission to Planet Earth is considerable -- it is comparable to all the other science programs in NASA combined. Yet compared to the value of the information, the cost is minuscule. Mission to Planet Earth contributes to the scientific basis designed to support policy decisions focused on protecting both the global environment and the world economy.

I would like now to elaborate on several aspects of Mission to Planet Earth.

1. What are the components of Mission to Planet Earth?
2. What is the Earth Observing System (EOS)?
3. Why must some instruments fly together?
4. How will NASA process the data from EOS?
5. What is NASA doing to get ready for EOS?
6. What role does education play in EOS?
7. How much will EOS cost?
8. What is the current status of Mission to Planet Earth?

What are the components of Mission to Planet Earth?

The President has proposed in the FY 1991 budget an aggressive, multi-agency research program to reduce the scientific uncertainties associated with global change. This program was developed by the Committee on Earth Science (now the Committee on Earth and Environmental Sciences, or CEES), a Federal interagency committee formed under the President's Science Advisor. With unprecedented cooperation, agreement, and a clear consensus, representatives of thirteen Federal agencies formulated the strategy for the U.S. Global Change Research Program. The priorities of this program are to document change in the Earth system using observational programs and data management systems, to carry out focused studies on controlling processes to improve our understanding, and to develop integrated conceptual and predictive models.

NASA's programs are central to the mission of the U.S. Global Change Research Program. Our major role is to apply our expertise in remote sensing to use the global perspective that is available only from space to understand how the Earth works as an integrated system. We call our program Mission to Planet Earth. It consists of (i) some nineteen near-term flight missions that will expand our knowledge of aspects of global change; (ii) an integrated data system that will be available by 1994 to draw maximum information from existing and upcoming missions; (iii) an expanded scientific research program; (iv) a series of small, focused missions known as Earth Probes; and (v) the Earth Observing System (EOS), which will provide comprehensive, long-term observations of the whole Earth and its component parts, sufficient to serve as the basis for predictive models of the future of the planet.

Mission to Planet Earth is unlike any other NASA Space Science Program. It is intended to broaden, with all due haste, our understanding of all aspects of the Earth system -- to broaden our understanding to a point where we will have sufficient knowledge of the intricate elements of the Earth system to make sound policy decisions. This program will require substantial and sustained funding levels, and will dwarf any other Space Science activity.

What is the Earth Observing System (EOS)?

The Earth Observing System (EOS), the centerpiece of the Mission to Planet Earth and an essential component of the President's U.S. Global Change Research Program, will provide U.S. leadership in the search to understand our environment. The science program for EOS reflects an integrated observational approach to many of the difficult science questions which face us while providing a direct response to the science priorities defined by the U.S. Global Change Research Program.

It is important to realize that EOS is a research program, which is designed to yield the maximum information about the Earth, and any impacts due to human activities, in the shortest possible time. It provides for a data and information system that will enhance the return for past and current missions, and missions that will fly in the next few years. It provides for an immediate and substantial growth in support for scientific research. It provides the comprehensive long-term global observations necessary to understand how the Earth responds to human interactions. In fact, a major potion of the funding for EOS will support the acquisition and analysis of data, and its scientific interpretation.

Only 40% of the funding is for space hardware. This is unprecedented in terms of funding distribution for space science programs. In planning this program, we recognized early on that the need to acquire data in an expeditious manner -- a manner which would support policy makers in their decision process -- warranted an aggressive program relative to data acquisition and analysis.

In order to meet the measurement goals of EOS science, the EOS program consists of two series of polar orbiting platforms with complementary payloads launched on Titan IV expendable launch vehicles. Each platform will be replaced every 5 years to achieve the 15 year mission lifetime goal.

The EOS platforms are designed to provide the comprehensive global observations to understand the Earth as an integrated system. The first platform, which will launch in CY 1998, is devoted to measurements of the surface of the Earth, and to the conditions of the lower atmosphere. The second platform, which will fly two and a half years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulation of the oceans, and the behavior of the solid Earth. In addition, our international partners, the European Space Agency (ESA) and Japan, are planning to build platforms which include accommodations for U.S. scientific instruments.

The requirement for global coverage from EOS dictates that these instruments be flown in a near-polar orbit. To avoid biasing EOS observations with the combined effects of diurnal and seasonal effects, sun-synchronous orbits have been selected for EOS. The 705-km, 98.2 degree inclination orbit planned for EOS will provide a quasi-two-day repeat pattern for frequent global coverage, while being in an altitude range acceptable to both wide-swath-width and high-resolution instruments.

The equator crossing time for EOS has been selected as 1:30 pm ascending node. This choice ensures strong solar illumination to improve the signal-to-noise performance of instruments measuring reflected sunlight. It is also designed to provide observations of terrestrial vegetation under conditions of near-maximum thermal and water stress. This choice of orbit also means that those EOS instruments with operational potential will be flown under conditions that are close to those of the primary NOAA polar operational mission.

The proposed payload groupings are the result of extensive analysis of accommodations, science requirements, international partner plans, cost, schedule, and other factors. The final allocation of instruments and other payload elements to specific platforms will be in accordance with selection confirmation decisions now underway for EOS-A and planned for September 1991 for EOS-B.

Why Must Some Instruments Fly Together?

Within the overall payload of EOS, there are sets of instruments which can complement each other in the production of desired observations. In some instances, certain instrument suites are required to yield corrective data. To do this, they must make their measurements simultaneously. These sets dictate certain minimum payload groupings around which alternative scenarios have been built and assessed. The time scales for significant variations in the phenomena being observed define the meaning of simultaneous. For EOS, there are four levels of simultaneity, which are detailed in the following paragraphs.

First, all EOS instruments need to be in orbit at the same time. This enables many of the variable components of the Earth system to be characterized globally every 1 to 3 days. This requirement is the reason behind the extensive set of planned observing capabilities. While many aspects of the Earth do not change on the time scale of days, all of the EOS instruments observe dynamic phenomena that do change rapidly.

Second, the atmosphere changes on time scales as short as 10 seconds. Changes in aerosol concentrations, temperature, water vapor distributions, and clouds can significantly affect the atmospheric contribution to signals received by optical instruments. This imposes simultaneity requirements on three separate sets of instruments to make their observations within a minute of one another and from the same perspective.

o The first group of these instruments includes those that measure the troposphere. If observations are made at the same time, data from these instruments can be combined to produce improved algorithms for atmospheric temperature and moisture profiles, cloud properties, aerosol column densities, and instantaneous rain rates.

o The second grouping includes the optical surface imagers. Although each of these imagers operates at different spatial resolutions, they share specific spectral bands. Surface imaging optical instruments always employ atmospheric corrections. For example, if the Moderate-Resolution Imaging Spectrometer (MODIS) and the High-Resolution Imaging Spectrometer (HIRIS) view the surface through the same atmosphere (i.e., simultaneously and from the same perspective), their data will be directly intercomparable before atmospheric corrections are applied. This will remove a major source of potential ambiguity from the results of such intercomparisons. Furthermore, the atmospheric corrections of the optical surface imagers may be aided by data from the atmospheric sensors in the first group.

o The third group of instruments are those that measure the different components of stratospheric chemical composition. If these instruments view the same stratospheric air mass at the same time, chemical concentrations from one instrument can be reasonably combined with those from another for a more comprehensive set of observations to use in comparison with localized photochemical models.

Third, vegetation canopies respond to environmental conditions on many time scales, but typical responses to drying conditions and variations in insolation may take as little as an hour. Consequently, those instruments used to study terrestrial vegetation need to make their measurements of a given site within an hour. This set of instruments includes all surface imagers within the proposed EOS payload. If these instruments are on platforms in the same orbit, even if they are on more than one platform, they can have the opportunity to view the same sites within 1 hour of each other. If they are flown in different orbits, there would only be intermittent opportunities for simultaneous viewing within the time requirement.

Fourth, measurements produced by the EOS Altimeter (ALT) and the Geosciences Laser Ranging System (GLRS) instrument both require precise knowledge of spacecraft location. The Global Positioning Satellite (GPS) Geoscience Instrument (GGI) on EOS is intended to provide this information. Flying these three devices on the same spacecraft allows them to share spacecraft location information.

The platforms are sized to accommodate those instruments which need to observe the Earth simultaneously, through the same column of air. All instruments that observe the surface of the Earth require substantial atmospheric corrections; knowledge of aerosol content, temperature, water vapor, etc. Thus, it is important to fly all the surface imagers and the instruments which determine atmospheric conditions on the same platform. This requires a total of eleven instruments, approximately 3000 kg of payload, to be flown together. This number of instruments is approximately equal to the number accommodated on the Upper Atmosphere Research Satellite (UARS); however, given the complexity of the EOS instruments, the total payload weight is 30% greater than that of UARS. In addition, EOS has the capability to manage over 10,000 times more data than UARS.

We have sought the constant advice and review of the Earth science community on the design of EOS, the choice of instruments, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations are the key to the success of the EOS program. Our fundamental concerns are assuring that the instruments are available in a timely fashion, and ensuring that our program meets the scientific priorities and requirements laid out by the U.S. Global Change Research Program. The size of the platforms, and their timing for launch, are simply an outgrowth of these science requirements. The challenge of the EOS platforms is directly related to the development, testing, and integration of the science instruments on those platforms, not the management of the platforms or the number of platforms which are built.

We will need to track the global environment for some years to ensure that we understand the changes, and the processes responsible for them. EOS is designed to yield fifteen years of continuous data. Since the EOS platforms are in polar orbit, where there is no servicing from the Shuttle, and a reasonable design life for a spacecraft is five years, each EOS platform will be replaced on orbit twice by an identical platform, at five year intervals.

How Will NASA Process the Data From EOS?

The EOS Program has put a major emphasis on the EOS Data and Information System (EOSDIS). EOSDIS is planned to acquire a comprehensive, global, 15-year data set, to maximize the utility of this data set for scientific purposes, and to facilitate its easy access by the research community. In addition to data processing, archival, and distribution facilities, the EOSDIS includes the necessary capabilities for the command and control of the spacecraft.

The development of EOSDIS will be initiated immediately by building on the existing infrastructure within the research community. It will implement an architecture which is open and distributed, so that it can evolve with advances in computing and networking technology. The near-term objectives are to support the research and analysis of data which both exist and will come from the near-term pre-EOS missions. In this way, the research community can gain valuable early experience in preparation for the future large EOS data volume.

Archived data sets, in addition to those from the EOS satellites, will include complementary in situ and satellite data. EOS will also involve the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the National Science Foundation, and other agencies.

There will be two types of data products: standard and specialized. Standard products will be generated and archived at Active Archive Centers around the country (all of which are existing data archives); the target time for the availability of engineering-level products is within 48 hours of collection, while the target for derived geophysical products is within 96 hours. Specialized products will be generated by individual investigators and made available to EOSDIS for archiving and distribution, as appropriate.

The EOSDIS data policy specifies that all data and derived products be available to all research users, with no preference given to EOS investigators. Research users in the U.S. and participating countries will pay only the nominal cost of data reproduction and delivery; they will be required to agree to publish their results and to make available supporting information, including methods for analyzing data. Research users in other countries may propose cooperative projects and associated "in kind" contributions (i.e., provide similar access to appropriate satellite, aircraft, and surface-based data) in exchange for access to EOS data on similar terms. Access to the raw data stream will be provided to operational agencies for forecasting purposes. NASA will provide for the commercial distribution of data on a non-discriminatory basis to all other users.

What is NASA Doing to get Ready for EOS?

During the next several years, our knowledge of the Earth will increase substantially. NASA will execute 19 Earth science missions, which will study various aspects of how the Earth works. The Upper Atmospheric Research Satellite (UARS) will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. A series of Total Ozone Mapping Spectrometer (TOMS) instruments, with potential flights in 1991, 1993 and 1995, will measure atmospheric ozone concentrations and contribute to our current models. The joint U.S./French TOPEX/POSEIDON mission will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer, to be launched in 1995 aboard the Japanese ADEOS spacecraft, will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and Shuttle Radar Lab, the topology of the land. Numerous Earth Probes missions in addition to TOMS are proposed; small missions in Earth science to pursue focused problems, e.g. the Tropical Rainfall Measuring Mission (TRMM). Also, our international partners, the Japanese, Europeans, and Canadians, will launch seven missions, some of which will carry U.S. experiments, and many of which we will help track in return for access to their data. In addition, the National Oceanic and Atmospheric Administration (NOAA) will continue to operate meteorological satellites.

To make optimum use of the data from these upcoming missions, we need to improve the computational capabilities in Earth science, and the access of researchers to this data through networks and archiving facilities. Included in the funding for EOS is substantial support to develop the EOSDIS, essential elements of which will be brought online in the early 1990's, in advance of the launch of the EOS platforms. EOSDIS will be used to derive maximum information from existing and upcoming missions; in turn, the data from these missions will be used to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms.

What Role Does Education Play in EOS?

Data alone, of course, does not yield understanding. That will require scientists interpreting the data, developing concepts for the processes which control the Earth, and building predictive models of its future. EOS also includes funding to effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to insure continuity of this research base into the future. The funding for scientific research has been included from the inception of the EOS program.

Education is the key to successfully addressing the habitability of our planet over the long term. The upcoming 19 Earth science missions mentioned earlier can be the conduit to educate the public, and particularly the young, about the importance of the Earth's processes. As with other space missions, EOS and other Earth science efforts will encourage young people to take up science and math with a concrete goal in mind -- working for the Earth.

For example, we have identified specific funding in the EOS budget to establish an Earth Science Fellowship Program, designed to increase the number of Earth scientists and engineers. A national competition will be conducted each year tc recommend and make awards for research support to graduate students enrolled in full-time Ph.D. programs at accredited U.S. universities. The first 37 fellowships were awarded in 1990 and the program will eventually fund up to 150 graduate students per year for the duration of the mission.

Awards are made for an initial 1-year term and may be renewed annually up to 3 years, based on satisfactory progress as reflected in academic performance and evaluations by the faculty advisor. Applications are considered for research on global biogeochemical cycles, radiation and physical climate interactions, the hydrological cycle, and solid Earth processes. Atmospheric and ocean physics, chemistry and biology, ecosystem dynamics, soil science, geology, geophysics, and cryospheric processes are all acceptable areas of research, providing that the specific research topic is relevant to NASA's global change research efforts (the Earth Observing System and Mission to Planet Earth).

How Much Will EOS Cost?

EOS will be the largest space science mission ever undertaken. Through the year 2000, the cost of EOS, including the instruments, the platforms, the data system, and the support for science, is approximately $17 billion in real year dollars (inflation included). The cost of all the EOS platforms and instruments, for example, is equal to what has and will be spent on the four Great Observatories for astronomy.

However, the key difference between EOS and other space science missions is how the money will be spent. In the EOS program, 60% of total funds will support ground operations, data and most importantly science. On most major missions, the majority of the funds goes for space hardware with only 30% allotted for science and data. The EOS cost ratio is driven by the volume of data, i.e., nearly 50,000 terabytes, and our determination that EOS produce reliable predictions of the future as soon as possible.

The EOS program will be managed by the Goddard Space Flight Center (GSFC). The FY 1991 budget includes funding to augment the workforce at GSFC in direct support of the EOS program and begins funding necessary to undertake construction of an EOSDIS facility. Both of these elements are integral to the total EOS program and required for its timely initiation.

However large the cost of EOS is in comparison with previous space science projects, its cost is truly minuscule compared to the cost of taking the wrong action on global change. For example, estimates for the cost to substantially reduce fossil fuel consumption can exceed a trillion dollars per year to the world's economy. EOS will give us the information to chart a course that both protects the environment and the economy.

What is the Current Status of Mission to Planet Earth?

NASA is prepared to begin development of the Earth Observing System and an Earth Probes program upon approval of the FY 1991 budget. Instruments under consideration for flight on the EOS-A series of platforms have undergone extensive review over the summer, with final reviews and deliberations on confirmation of the instruments for the platforms underway. Final confirmation of the EOS-A series payload, which authorizes development of the instruments, is expected early this month (October). The Request for Information (RFI) for development of the EOS Data and Information System (EOSDIS) is also scheduled for release in early October, leading toward a projected February 1991 release of the Request for Proposal (RFP).

The National Research Council (NRC) review of the EOS program concluded in July that "scientific arguments for simultaneous measurements have been developed by NASA for two specific research areas: the role of clouds in climate and the fluxes of the trace gases. With regard to these two cases, we conclude that the number of instruments that must fly together requires at least one large satellite." The NRC report also validated NASA's approach to developing the science program and data system.

Two Earth Probes, a Total Ozone Mapping Spectrometer (TOMS) instrument and the NASA Scatterometer (NSCAT), were confirmed earlier this year for flight aboard the Japanese Advanced Earth Observing Satellite (ADEOS) in 1995. Pre-development studies continue on the Tropical Rainfall Measuring Mission (TRMM), while procurement of ocean color data from industry (via commercial development of SeaWiFS) is in process.

In addition to these activities, other ongoing elements of Mission to Planet Earth are also making significant progress. Both the Upper Atmosphere Research Satellite (UARS) and the TOPEX/POSEIDON mission are on schedule for their respective 1991 and 1992 launch opportunities. In July of this year, the United States concluded a landmark agreement with the Soviet Union to fly a TOMS instrument on a Soviet Meteor-3 spacecraft in August 1991 to continue the vital global ozone data set.

SUMMARY

Mr. Chairman, we have a responsibility. We know that we are affecting our global environment, yet the outcome of these effects on the world that we will bequeath to our children and our grandchildren is unknown. We cannot let this ignorance persist. We need to undertake the Mission to Planet Earth and the entire global change research program of the Federal government so that we can reduce the uncertainties in the pending global changes, and be, as a result, wise stewards of the future of the planet.

Thank you, very much.

Mr. NELSON. Mr. Packard?

Mr. PACKARD. Thank you, Mr. Chairman. With the fiscal constraints that we're struggling under, as you well know, since it's being considered at the time that deficit reduction is going to force difficult funding choices for NASA and the Congress, what are the estimated costs? And what does that include? And what is the estimated life-cost cycle and what does that include? And how much of the development cost is for EOS data management system and how much is for life-cycle cost?

Dr. FISK. Okay. Let me give you a whole series of numbers to answer this. Between now and 1990, one decade from now, in real-year dollars that includes inflation and everything else in it, no hidden cost, the cost is about $17 billion. If you want to go out to the end of the mission, which occurs in 2019, those 20 years beyond that, I'm reluctant to give you a number with inflation because I have no idea how to predict it. But over that period of time, let me put it in fiscal '90 dollars, it would be a $30 billion cost. If you want to divide this between space hardware and the data system, about 40 percent of that is space hardware, 60 percent is the data and the science associated with it. So, if you like, between now and 1990 it's probably $8 billion for space hardware and 9 billion—now and the year 2000, it's 8 billion for space hardware, 9 billion for the data system, real-year dollars. Between now and the year—the end of the program in FY '90 dollars, it's 12 billion for space hardware and 18 billion for the ground.

Mr. PACKARD. And how much are we expecting, how much cooperation and participation are we expecting from the international community?

Dr. FISK. Roughly speaking—thank you for pointing that out. What I was describing a few moments ago is the U.S. portion of that. Now, in addition to that there is a very major Japanese portion and a very major European portion. The Japanese will fly a platform of their own, the Europeans will fly 2 platforms of their own, and both the Japanese and the Europeans will have instruments that fly on our spacecraft and we, in turn, instruments flying on their spacecraft.

It is a little difficult sometimes to estimate the total dollar contribution of the Europeans and the Japanese because of the differences in accounting systems. But I think it's a fair statement to say that together the Japanese and the Europeans will contribute about an equal amount to what we will be contributing.

Mr. PACKARD. And with the experience that we seem to be struggling with in our international agreements on the Space Station and many of the uncertainties there, are our international partners on EOS as enthusiastic as we would like, or more so? Or what is their reaction?

Dr. FISK. They're very enthusiastic. I think all of us recognize that the only way to do this program is internationally. I mean, this is a world problem. This is not a United States problem. This is a world problem. We all have a responsibility to use our scientific resources to help answer the questions. The developing nations, in Europe, Japan, and the United States, will bring the space technology to the table. That's what we can do. But we also anticipate efforts, not maybe so major in dollar numbers, but certainly rela-

tive to the abilities of the countries to pay, from the developing nations of the world. Because after all, some of the problems we face are in developing nations. The rain forest in Brazil, desertification in Africa—I mean, these are the things that have to be dealt with as well, and we anticipate that those countries will bring ground measurements, to be measurements on the ground to support our calibration of our spacecraft measurements and other things. This needs to be a worldwide cooperative effort.

Mr. PACKARD. Do you have any feel as to what percentage of the total NASA budget would be earmarked for this program?

Dr. FISK. Well, it—I guess, since you probably know more about the budget arrangement than I do—

Mr. PACKARD. I don't think any of us know very much, for the record.

Dr. FISK. —I should ask you what the total NASA budget is likely to be like.

This program, obviously, if you're spending 17 billion now and the year 2000 is going to run at a $1-1/2 billion a year level or so, and then it depends on—you know, if you had a $15 billion NASA, that's 10 percent of the budget.

Mr. PACKARD. Yes. Thank you, Mr. Chairman.

Mr. NELSON. And we're looking at a $30 to $37 billion program over 20 years; is that right?

Dr. FISK. I think it's 30, 30 billion over 20 years. Well, I guess I'd count it as 25 or so years.

Mr. NELSON. How much of that is for the data management system?

Dr. FISK. Sixty percent.

Mr. NELSON. Sixty percent of that.

Dr. FISK. That's correct. That's, well, let's say 18 billion.

Mr. NELSON. Is that what employs the bulk of the 600 to 1,000 people?

Dr. FISK. No. That's a minor—that would be—this comes in different parts. There is the interdisciplinary investigation, which is my number of 600 folks or so fully staffed. But then there are, of course, the people who develop algorithms. Those are additional people. The people who operate the data system. There are a series of distributed active archives throughout the country, and those people will be staffed. I mean, this is a very large program, as you would imagine, in terms of number of people involved.

Mr. NELSON. If our first cut at this budget summit agreement shows that NASA would come out in the range of about $14 billion, fiscal year '91, that for fiscal years '92 and '93 that it would be about a 10 to 12 percent increase—now, this is all very rough, and, of course, it's subject to appropriations, but just trying to get the best cut on it. With that kind of increase, from your projections on EOS would it have to be less in '92 and '93?

Dr. FISK. I don't know that I can—I don't think I can easily answer that question because it depends on, you know, what else is happening in the agency besides EOS. I mean, you will have a certain number for Space Station in a $14 billion NASA which is different, presumably, from the President's budget, which was a $15 billion. And then you have to ask how does that project and so on.

Let me—I mean, clearly, as in any new start whether it's Space Station or a science program, and we have in the fiscal '91 budget this is 230—the President's budget was 232 million for EOS, Mission to Planet Earth, and it's—that's just the beginning. I mean it's going to grow and it'll—then it becomes 500 million next year, it becomes a billion something the year after, and it levels off at the $1-1/2 billion per year level.

And that by itself, of course, is a much bigger growth than 10 or 12 percent per year, as you would expect for a developing a new start, and then the question is what offsets exist in the budget that would allow that to grow and still maintain a 10-12 percent. But I'm sure you know that it will be very difficult to have the space program that we currently have, have it as active as we'd like it to be, and have the growth at 10-12 percent.

Mr. NELSON. Do you have any descoping option?

Dr. FISK. Well, let me—let's talk about that, because you raised it in your opening remarks. And you—let me tell you what the dilemma is with this and what we have to come to grips with.

You're trying to understand the feedback mechanisms that occur on the Earth. You know, you say to yourself, "Look. I don't know how the Earth is going to respond to all these greenhouse gases and things that I'm putting into it." And a lot of things could happen, some of which are beneficial and some of which are very detrimental. I mean, for example, people worry about how many clouds there are going to be, and you say, "Well, there're 2 kinds of clouds. There are low clouds and they are good because they reflect sunlight, cool the Earth. And there are high clouds and they are bad because they trap the heat. And so, if I put greenhouse gases in the atmosphere, CO2, which do I get? Do I get more low clouds? Do I get more or fewer clouds, first of all? It could go either way. Do I get—are they going to be low or are they going to be high?" That's a feedback mechanism. If I get more low clouds, we could offset greenhouse warming, maybe it's not a problem. We got more high clouds, it could accelerate greenhouse warming and make it occur much faster than we would like it to.

And there are—you could list over and over again things that could happen which would drive the system one way or the other. There's methane in the peat bogs in the tundra. If the Earth gets a little warmer, will the tundra start to melt? Will that release methane in the atmosphere? It's a greenhouse gas. Will it accelerate the problem?

Will sea levels go up or will they go down? Well, gets warmer, you'd think the ice would melt and sea level would go up. But there's another theory that says, If I have warming, I still get—I get more moisture in the air. I still get precipitation in the poles, but I get more of it. And it still occurs as snow, so the poles grow and sea levels sink.

You can just list over and over again the things that you just don't know which way they're going to go. Now you got a problem, and you say, "Well, I'm going to make a policy decision at some point as to what to do." And, if I miss some basic mechanism here, I could really make the wrong policy decision. I could decide that greenhouse warming is not a problem and everybody relaxes. I could decide that it is a problem and when it's not. I mean, you

could go either way, if I leave something out. And the measurements that we make on EOS are, according to all the scientists that we deal with, the minimum set of measurements that we're going to make.

So the only way we're going to save money, the only descope option that we have is to not measure something, and I don't know what it is. Because if I don't measure something, I really run the risk that I didn't measure the important thing for controlling the feedback mechanism.

Mr. NELSON. Mr. Rohrabacher?

Mr. ROHRABACHER. Thank you, Mr. Chairman. I'll be brief.

Dr. Fisk, perhaps you could tell us what's been learned from the Hubble Telescope debacle that's going to be put to good use in this project?

Dr. FISK. I'll try not to make flippant answers. The Hubble—I mean there was a—the lessons are not direct, the following sense. Hubble is—had one part of the spacecraft which was not redundant. That was the mirrors. Got them wrong and then you're stuck with it. Now, the fortunate thing about the EOS platforms is they are highly redundant. You know, there is no single point failure in this system other than the platform falls apart. I mean it's not, you know, there's nothing in it that—the power system, the data systems and everything are all redundant. So, if there is a failure in the platforms, it's not going to be catastrophic in the same way that we—that the mirrors have caused us difficulty in Hubble.

I think that, you know, comparing the platforms you really ought to compare it to Magellan, for example. There's a case where we've head some difficulty with the spacecraft, but the spacecraft is incredibly robust. All this robustness and redundancy is built into the thing. We're mapping away, having a wonderful time. And, you know, those are the comparisons I think to make.

I mean the thing—the great observatories are unique in the spacecraft because they have one set of mirrors in them in some cases, and we know a lot more today about how to build mirrors as a result of Hubble. But I don't think it's—they're applicable lessons. I think the lessons that have been learned over the years in building many other kinds of spacecraft, and we've learned them well and we should be in good shape.

Mr. ROHRABACHER. Well, just a little bit about the funding. Can we rely now, which we've seen in terms of the Space Station and higher levels of funding and lower levels of funding and threats to cut off funding—how is this going to affect your planning in this project?

Dr. FISK. Well, the most difficult thing, as you point out, in doing any project management is adjusting to the changes in funding levels over what you expected. The one thing we are doing in this program and we—I think is a very valuable thing to do is that we're building as much resiliency into it as we can. You'll find when you see our selection of instruments, for example, confirmation of instruments on EOS-A, that we have left enormous power margins and weight margins and redundancy in the data system, and, you know, we've tried to reduce all the possible risk factors to as low as we can make them so that we will not experience from

our side either technical showstoppers or cost overruns in the course of doing business. Those are things I can control.

But the program assumes that the budget will grow next year and grow the year after that. And, if it doesn't, then you can't execute this program as planned. That's a simple fact.

Mr. ROHRABACHER. Those are fairly, I don't know if I can call them unreasonable expectations, but those are certainly expectations that don't have risks involved themselves, because I have no idea, and I don't think anyone here has any idea. If the economy goes down next year, if we are in a recession next year, the budget crisis that we face this year could just seem small in comparison.

Let me ask you that. If we do have budget problems in the future, and my last question would be that if we do have these budget challenges in the future would you ever consider reducing some of the redundancies? Would you think that, perhaps, some of the fail-safe programs and the backups that make these redundancies a safeguard, maybe we could do without some of them?

Dr. FISK. I'd, only if I was going to—wanted to relegate my successor many times removed here to the kind of problems that I experienced in explaining Hubble's. I think that's the problem. We need to succeed with this mission. We need to—I mean, there's a lot of people that are going to depend on the outcome of this. We can't put a platform up and then have a failure in the system and lose data. I mean, that would set the program back.

The cost for redundancy is not all that high if you plan for it in advance. It's simply prudent management on the program.

You know you talk about the cost, and I understand it's large. But, you know, don't forget, it depends on what you want to compare it to. We're forced to compare it to the deficit, to the Federal budget, to the amount of money that NASA could get, and I understand that. That's the real world. But we have about a $13 trillion a year world gross national product and 80 percent of that is generated through the consumption of fossil fuels, which are in fact what it is that is causing or is the potential cause for greenhouse warming. And we're going to have to make some very hard policy decisions which impact that $13 trillion world economy. And we're asking to spend a billion, a billion and a half dollars a year, which is a hundredth of a percent of that world gross national product, to get the information needed to protect the other 99.99 percent.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Mr. NELSON. Mr. Skaggs?

Mr. SKAGGS. Thank you, Mr. Chairman.

Dr. Fisk, I'm sorry I wasn't here for your opening statement, and I hope I'm not going to be covering ground that you've already seeded and harvested. My questions really revolve around the notion of lots of eggs in one basket, and if the basket drops, do we have a lot of scrambled eggs. And I continue to be troubled by what I read in the popular and trade press about the risks that we're taking by loading too much, arguably, onto a single platform. I'd like to ask your observations about a couple of the sub-issues there, one having to do with the level of importance we ought to place on simultaneity of observations through that approach versus launching a number of smaller missions in train. And also—well, why don't you take that one first?

Dr. FISK. Okay. In the case of the instruments that are to fly on the first platform, the so-called EOS-A, I think the argument for simultaneity is compelling. We're going to be looking at the surface of the Earth. We're going to have to make in each case fairly major atmospheric corrections to those measurements, and the atmosphere changes very quickly. Clouds blow in and out, aerosols change, dust changes—everything changes on very short time scales. And so the only practical way to do that is to look simultaneously through the same column of air, which says you're on the same platform. This is a point that the Academy went into in great detail and shares our opinion on that subject.

Now, in the case of the B series, the argument is not compelling from a science point of view. There are some instruments that need to be bunched together because they are looking at, for example, the chemistry of the atmosphere, and there you are looking at rate changes between different constituents of the atmosphere and you, obviously, have to look at them at the same time, otherwise you're not seeing particles coming and going. But all the instruments don't need to be together on the same platform.

Mr. SKAGGS. Well, let's, if I can lead you a bit, talk about this argument of putting all things in one basket, which is the issue.

Dr. FISK. Okay. In the case of EOS-A, it's going to have about 10 or 12 instruments on it on a fairly large platform. People tend to think of this somehow as Battlestar Galactica. I mean, there are 10 instruments on UARS, which is going to fly in 1991. I think there are 12 instruments on Voyager. I mean, you know, that having 10-12 instruments is itself not a big issue. They are fairly large instruments. The platform is about 30 percent heavier than the UARS spacecrafts. This is not outside our realm of experience.

Large platforms also have one big advantage and the issue is redundancy. I mean, if you want to carry 2 tape recorders, you want to carry 2 independent power systems, if your thermal system wants to be completely redundant—well, if you have a very limited spacecraft, I mean, that's hard to do. I've got a big platform with an enormous weight margin available to me and I can build redundancy into the system.

So the only failure mode that I can't protect myself against in a large platform is launch failure. And so the only issue is did I somehow have an unreliable launch vehicle that was going to fail?

Now, that is always a risk. What do you do to protect yourself against that risk? Well, first of all, you put yourself on a reliable launch vehicle, one that's got a good heritage and history associated with it. The Air Force is scheduled to fly something like 40 to 50 Titan IVs before we launch EOS-A, so there's going to be a lot—and, if it isn't working, the Air Force is going to have to fix it because all of the national security payloads depend on that being a reliable launch vehicle. So there ought to be a good heritage by the time we need it.

Secondly, you say, "Well, Art, even if I get the random failure here, what can I do?" Well, the program allows for the purchase essentially of, almost simultaneously, all three sets of instruments. There's a series of platforms, you know, to get the 15-year life. And so once we build EOS-A, within 1 to 2 years we will have a fully completed set of instruments which are scheduled to fly on the re-

placement platform, but are available within 1 to 2 years after the launch of the first one. So, if we had a catastrophic failure we could assemble another one very quickly and put it up.

The other point which perhaps you—I talked about a bit in my opening remarks is that at the moment there are only 2 launch vehicles available out of the West Coast where we have to fly. There's Deltas, which are too small by everybody's standard. Individual instruments don't fit on Deltas. And there's the Titan IVs. And so we'd, in order to get this medium class, smaller launch platform into the system, we're going to have to develop a launch vehicle. They're going to have to have a new launch vehicle out of the West Coast, something in the Atlas class, and that doesn't now exist. Not that it can't be built. Not that you can't build a launch pad out there. But at least today it doesn't exist.

Mr. SKAGGS. One additional question, if I may, Mr. Chairman.

Just looking at an AIAA paper, which I'm sure you're familiar with, the comment is made questioning the effectiveness of cloud studies from a polar orbit, which I don't know enough about to respond to intelligently. I'm sure you do.

Dr. FISK. Okay. The issue is the following. The reason you go into polar orbit—it's called the Sun synchronous orbit—is that literally you want to see the Earth, a point on the Earth at the same time every day. That's how you put yourself in orbit. And the beauty of that is you—first of all, in the polar orbit you've got global coverage. You can see the whole Earth every day. And on top of that, if you go over at the same time every day you don't have the uncertainty of did the Sun angle change, what impact did different Sun angles have on vegetation. You've got a controlled condition for measuring that point on the Earth.

But now, perhaps insult people who live in Louisiana. But, if you went over Louisiana at four o'clock in the afternoon every day, you'd think it always rained in Louisiana because it rains at four o'clock. Or perhaps Florida. I've always been in Florida. It rains at four o'clock. And so you can be biased, then, in seeing particular kind of phenomena if you look at them every day. There are some measurements like rainfall and cloud covers and so forth that you need what's called diurnal coverage. You need to go over at different times each day to see that.

And so the plan is to do the polar platforms for global coverage, Sun synchronous coverage, but then to have a series of Earth Probes, small missions to do those small set of measurements which need to be done with diurnal coverage. There is a thing called Tropical Rainfall Monitoring Mission, which will go around in an equatorial orbit to measure tropical rainfall because that's something you have to measure diurnally. There will be some additional cloud measurements that need to be made, again to give you diurnal coverage, and the program includes that. It includes both the polar platform and the Earth Probes to do the diurnal coverage.

Mr. SKAGGS. Thank you. Thank you, Mr. Chairman.

Mr. NELSON. There has been some concern about the—your office Strategic Plan has a core program for science, and then EOS is considered outside of that core program. The Strategic Plan, of which we have a copy here, says that when such initiatives are un-

dertaken the appropriate resources must be added over and above the baseline or core plan.

Now, if NASA has to absorb some funding cuts from its projections over the next several years, would you recommend funding the core program as close to the President's request before allocating any of the resources to the EOS program?

Dr. FISK. This is kind of a "which puppy do you want to drown" question, but the answer is yes, I would recommend the core program. But that's an easy answer to give for the following reason. So much of the core program is tied up in operational missions—Hubble, Galileo, Magellan, Mars Observer—missions that are almost completed, for which we've all invested hundreds of millions of dollars like Mars Observer and UARS and the R&A Program. I mean, they are not things that you can—that any of us would turn off. We won't turn off Hubble to fly EOS and so it is a fairly simple statement to say, "You got to do that core," because we've already invested in that.

Mr. NELSON. Why don't we digress here for just a moment, and give us an up-to-date on Hubble?

Dr. FISK. Well, contrary to anything you might have heard, Hubble is doing actually very well. The spherical aberration is there and it's—we understand now how it came about, and I'll be happy to talk about that if you'd like to know more. The Allen Panel has met and drawn its conclusions and is writing its final report now.

But the status of the Telescope itself is very good. At the end of the—when we first discovered this spherical aberration we knew that we could do spectroscopy, measuring the individual lines in the spectrum, and we knew we could do ultraviolet astronomy very well. You remember that Hubble had like a factor of 10,000 improvement in ultraviolet astronomy over anything that had ever flown before. We probably still have safely a factor of 1,000, and so we knew we were going to do very well. But the thing that has delighted and pleased us over the last month or so is realizing how many good pictures we can take with the Hubble as it exists today.

You've probably seen the picture of the 1987 supernova, and the nice thing about that picture, it has a spherical ring around the supernova. That's a better picture than anyone has from the ground and by a substantial amount, and you know that everybody from the ground has tried as hard as they could because the 1987 supernova was the biggest event in astronomy in hundreds of years and everybody turned their best telescopes at it, and they couldn't do anywhere near as well as this single picture we took from Hubble. And the reason for that is that, even though there is this spherical aberration, the Hubble signal still has a very narrow peak at the resolution of a 10th of an arc-second. And so anytime you look at an object that has a reasonable contrast to it it's a very simple matter to pick out that peak, suppress the background which is caused by the spherical aberration, get all the resolution and clarity out of it that you expected from the original Hubble.

Now, we still are unable to do very faint and very low contrast object. If an object is very smooth and has no contrast to it, this technique doesn't work. But, fortunately, some of the most interesting pictures in astronomy have high contrast with them and we

are getting pictures now just as good as we ever expected Hubble to do.

Mr. NELSON. That message I don't think has gotten out.

Dr. FISK. I am well aware of that.

Mr. NELSON. So you're saying where you have the contrast that with your ability now to take out the background which is caused by the aberration that you can get the clearest of picture—

Dr. FISK. Right.

Mr. NELSON. —as you would had there not been the aberration?

Dr. FISK. Let me be specific. That's 1987, a supernova picture. If I had had a perfect Hubble, no spherical aberration, and I held up the picture from that and I held up the picture that you saw, you would not see any difference.

Mr. NELSON. Well, NASA needs to get its PR department cranking overtime to get that message out. Now, we had gotten that message around here, but the basic real world print press out there isn't printing.

Mr. ROHRABACHER. Mr. Chairman, could I—

Mr. NELSON. Please.

Mr. ROHRABACHER. —a question on this. Does that mean that later on when these much touted adjustments are made that we will be getting the same quality picture after the adjustments are made of the same supernova?

Dr. FISK. What you'll pick up with the adjustments is—I mean, we'll go up and fix the instruments to compensate for the aberration in the mirrors and then we can do all the faint, low contrast objects as well. We still are missing those low contrast.

Mr. ROHRABACHER. The quality of these objects that aren't so faint, the ones that we're talking about, they're more demonstrable. The quality will be the same.

Dr. FISK. Absolutely.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Mr. NELSON. The rescue mission in '93, describe that to us.

Dr. FISK. Well, we're in the process of taking a second-generation wide-field planetary camera, which we've always had in the budget and ready to go, and modifying that now to correct for the spherical aberration, and it's a very simple correction. There's a whole series of little mirrors in that wide-field planetary camera, and essentially you just pick out the existing mirror and put in a mirror that has an equal and opposite aberration to the primary mirror of the Telescope, so it just—end of problem.

Remember, the virtue of our aberration—it's a perfect aberration. So therefore it's easy to correct. The instrument is then built, will be ready in sort of the summer of '92 so it can be integrated into the carriers of the shuttle and so forth, and then flown in June of '93. It's a fairly—it'll be an interesting thing to watch, but hopefully not too complicated, because everything is designed in those instruments simply to pull them out of the Telescope, with the astronauts, put it back in the shuttle bay, pick up the new instrument, put it in. The latches, of course, we spent a long time designing and they were a big problem on the Telescope, but they are designed to put those instruments in with exactly the right alignment to work. And so that—and once you've done that then

you, at least as far as the wide-field planetary camera, it will not experience—not see any aberration.

Mr. NELSON. Are there other instruments that need to be fixed?

Dr. FISK. Essentially all. I mean, in order to take the aberration out, each instrument needs to be replaced. Now, the faint object camera, the Europeans didn't have a second generation and I don't believe they're going to try and build one. So they will have to live with this spherical aberration. But the nice part about the faint object camera is it's really—it does most of its good work in ultraviolet, so they still got this factor of 1,000 over anything that anyone did before.

We will follow the second generation WFPIC with the space telescope imaging spectrometer, which is a replacement for some of the spectroscopy instruments and the wide—the faint object camera, and then later in the decade we will open up the Telescope to infrared astronomy. It's also capable of doing infrared astronomy, and there is a new instrument called NICMOS, and I'm sorry I don't know what it stands for, but it essentially is an infrared camera to be used on the Telescope. And it too will be modified to take out the aberration.

Mr. NELSON. The National Research Council report noted that interim missions such as UARS, TOPEX and Earth Probes are intended to gather data that are essential for the U.S. Global Change Research Program. Then it recommended that if budget constraints arise it would be preferable to delay the launch of EOS rather than forego or diminish the effectiveness of these near-term projects. In other words, it's suggesting which puppy to drown.

I take it you don't agree with that recommendation.

Dr. FISK. Well, I hope we don't get to that point. There's a certain pragmatism in this, that I'm not sure quite how the comparison works. Because—and, of course, UARS and TOPEX are nearly done. I mean, they're not going to be delayed or anything. We have final integration on those spacecraft and they're scheduled to fly in late '91—mid '91 and '92.

In the case of Earth Probes the entire budget will probably never peak over $100 million a year and it's an explorer program. It's that kind of level for—and that covers doing TRMM and TOMS and Sea Wifs and all the things that people want to do. And so, in some ways, you know, you—you don't have the kind of money in Earth Probes that really is impacted by the kind of money that we need in EOS, and I have every intention of doing Earth Probes on time and on budget, and I don't think I'm going to have to delay.

The EOS funding situation is—it's going to require strong support for that budget and it's almost independent of what we do on Earth Probes.

Mr. NELSON. Before we recess to go vote, would you give us a quick synopsis of entering the new era of great planetary exploration and what amendments would have been made since this started about a year, year and a half ago, and of which you were talking about the first probe that—which was the one we launched before Galileo?

Dr. FISK. Magellan.

Mr. NELSON. Magellan.

Dr. FISK. Of course, Magellan is doing very well, and as—again, I'm not sure how our publicity is doing on it but the spacecraft is doing very well and producing spectacular pictures of Venus. And I think it's a wonderful testimony to the robustness with which we build our spacecraft. I mean, despite the fact that it got a little errant there and wandered off. It knew where home was and came looking for us, and it's doing well.

Galileo is heading towards you at the moment at 53,000 miles per hour, and it will come here in December, about 400 or 500 miles up. It will go around the Earth and then swing out again, come back in 2 years and then head to Jupiter.

Mars Observer is on budget, on schedule. Launch in September of '92, a little less than 2 years from now.

Craf and Cassini are under way. We've got a little hiccough in the Senate at the moment because the funding for Craf is not in the Senate mark as it came out of the subcommittee. It is in the House, and that will have to be resolved in conference.

If we—if all of that is funded on schedule, we essentially—you know, I guess the way I like to think about that is the 15th of December when we started mapping at Venus with Magellan we will have a planetary mission in its prime exploration phase continuously now from the 15th of December to the year 2006. Because you'll have Magellan at Venus for several years now mapping the planet, Mars Observer gets to Mars in '93 and is there to '96, Galileo is at Jupiter '96 to a little short of 2000, Craf gets to its comet at 2000 and is there to 2002, and Cassini gets to Saturn in 2002 and is there to 2006. So, as far as I can tell, as of the 15th of December we have a very vibrant planetary, U.S. planetary program.

Mr. NELSON. And then 2007 we land on Mars?

Dr. FISK. Sounds good to me.

Mr. NELSON. Okay. The committee will stand in recess. And we'll come right back and take the second panel, if you want to come up and join Dr. Fisk.

[Recess.]

Mr. NELSON. Well, let's start with our second panel: Dr. Bishop, Dr. Eddy. Again, if you will not read your statement, let's just talk and we'll get on into the questions.

Dr. Bishop?

Dr. BISHOP. I think, Mr. Chairman, if it makes sense to you, we'd like to—Dr. Eddy and I would like to take the report in the order that the portions occur in the report, and Dr. Eddy go first.

Mr. NELSON. Okay.

STATEMENTS OF DR. WILLIAM BISHOP, SPACE STUDIES BOARD, COMMITTEE ON EARTH STUDIES, DESERT RESEARCH INSTITUTE, 2505 CHANDLER AVENUE, SUITE 1, LAS VEGAS, NEVADA 89120; AND DR. JOHN A. EDDY, CHAIRMAN, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH, P.O. BOX 3000, BOULDER, COLORADO 80307-3000

Dr. EDDY. Thank you, Mr. Chairman. I'm also happy to be here, and speaking on behalf of the scientists who work for the Global Change Program and the goals that are behind EOS, I'd like to thank your subcommittee and committee for the strong support

that we see for it. It's very heartening to work in science toward this end and to know there's this level of understanding.

I would like to make three points, and I do that in my testimony. I will just summarize those and then have a few other remarks.

I chaired a panel that was appointed by the National Research Council to look at the U.S. Global Change Research Program in toto, of which the EOS and the Mission to Planet Earth endeavor in general is, as you know, a very major element. The major findings of our group are these three, the three points I want to make.

The first is that the panel found that the program as it's defined in the President's budget for fiscal year 1991 is a sound approach toward reducing the scientific uncertainties associated with global change issues. As background, it found also that the investment in spaceborne observations, although they comprise such a major part of that global change research budget, was a prudent one, given the pressing need to initiate long-term observations of environmental parameters.

The third point is to remind you that this plan that was reviewed by the NRC, which includes the new start for EOS, is one that has been very heavily vetted and very heavily examined. It reflects the priorities established, I think, not only by an unprecedented level of interagency collaboration through the Committee on Environmental and Earth Sciences, but through studies that have been going on over the past decade and what was needed here. It's also coincidental with the goals of the broader International Geosphere-Biosphere Program and the World Climate Research program.

On this point I'd like to give my own opinion, and that is there would never have been or there could never be a national program organized to look at global changes in the broad were there not something like the Earth Observing System. That is the linchpin that ties the U.S. program together, that gives it a kind of flagship initiative. The reason we can—again, the reason we can talk as scientists about giving more reliable predictions about future environmental change including climate warming, but a good many other issues, is in part that the technology now exists to look at the Earth from the vantage point of space and that there is a technology now to have the data systems of the sort that EOS-DIS puts into place. That these are the developments that have made possible, I think, this hopeful look to the future.

And, as for the cost of it, again Dr. Fisk has said that very eloquently, but I can think of no better investment in the future. No better investment that we could bequeath to not only scientists, but inhabitants of the Earth, for the future than to initiate such a program as the Global Change Research Program, and our committee looking at it felt very strongly that way.

An element of it is to put in place something that's not been in place before, and that's a long-term measurement strategy that would provide for scientists 10 years from now, 20 years from now, 30 years from now, the records that we wish we had in hand now to answer these policy questions.

If I can also express a personal view in these few minutes, it is that doing it piecemeal or doing it in less an initiative than the bold one expressed in EOS and Mission to Planet Earth—I would

include in that Dr. Fisk's Earth Probe initiative. Doing it less than that is just not going to hack it. He has given, I think, today a very good scientific argument as to why the need for this kind of centralized observing from a single platform.

I would add to that another point. That is, that if we try to guess what the problems are going to be in the environment in the future I can tell you with certainty as scientists that we're not going to do that very well. None of us anticipated the ozone hole before those first measurements came from the British a number of years ago. The stresses on the environment, the interconnectedness of the system makes it certain that there are going to be environmental surprises that are grave. I'm not so sure personally that the concern about global warming will always be or will be for the next 5 years the leading issue in people's minds because I suspect others will come up. With increasing population and increasing development, we can be certain that these problems are going to grow.

The reason I say that here is to say that in order to do the best job of anticipating that we can it is necessary to put into place a comprehensive strategy, something that will observe the system, that will look at it as a whole. I think if you try to do that by subdividing it too much you're going to miss, perhaps, the most pressing problems, whatever they are, and they'll come at us from directions that we can't anticipate.

Also on that point, I don't think that a piecemeal approach is also appropriate to the kind of leadership that the U.S. now enjoys in this area. If I could only leave one thought with you today, it's that so much hinges upon the support for the NASA Mission to Plant Earth initiative including EOS. That it has national and international implications that I don't think can be exaggerated. As I've said, it is the cornerstone of the U.S. Global Change Research Program, an effort that involves a dozen agencies working actively here, all of whom have reviewed the EOS initiative and endorsed it as part of a broad governmental plan.

So, it provides the launching force to get going on this thing that I think we need. It's also the keystone, in my view, of the broader International Geosphere-Biosphere Program that now has enlisted in it the scientists and the governments of 40 nations, including all of the major ones on Earth, and that hinges so much upon our ability to begin to observe the vital signs of the Earth or to put the Earth in intensive care so we can see what is a real crisis and what is not.

I think that we're being watched internationally about that. Not skeptically or any way other than positively, but I think where we go others will follow, and I think that makes this a terribly important thing and I don't think there is a more important thing that we could do for studying the future of the Earth than to do this if it were for nothing but a symbol. That yes, we're serious about looking at environmental conditions and this country is ready to take a lead in it, and I think the NASA program does that.

I have gone—given some personal remarks beyond those that were put together by the, one of the 2 committees that you're hearing from today. I want to emphasize again the committee findings were a strong endorsement of the Earth Observing System as a key

element to the Global Change Research Program, and that's a thing I hope you'll remember.

Thank you.

[The prepared statement of Mr. Eddy follows:]

STATEMENT OF

John A. Eddy

Chairman
Panel to Review the FY1991
U.S. Global Change Research Program
National Research Council

BEFORE THE

Committee on Science, Space, and Technology
Subcommittee on Space Science and Applications
U.S. House of Representatives

Hearing on
The NASA Earth Observing System (EOS)

Tuesday, October 2, 1990
Room 2325
Rayburn House Office Building

Mr. Chairman:

I have been asked to appear today on behalf of the National Research Council Panel to Review the FY 1991 Global Change Research Program of the United States: a broad and pragmatic program of research in which the NASA Mission to Planet Earth is a key element.

Early this year the NRC was asked by the President's Science Advisor for critical assessments of the FY 1991 U.S. Global Change Research Program and in that context of the Earth Observing System, as defined in NASA's FY 1991 budget request. Our final report, "The U.S. Global Change Research Program, An Assessment of the FY 1991 Plans" was delivered to Dr. Bromley in August, and is included in the materials that I shall leave as part of my testimony. The assessment was carried out by two panels, one addressing the USGCRP, which I chaired, and one on the EOS itself, chaired by Dr. James Baker. Our combined report presents the considered opinion of a panel of distinguished scientists from 20 universities and research laboratories with additional input from the NRC Committee on Global Change and from many other scientists in many disciplines. I hope that my statement here today, as it reflects our findings, will help establish the importance of the EOS new start in the context of both national and international plans to improve our understanding of the Earth at a time of significant change in the global environment.

The points I should like to make are three: (1) Our Panel found that the USGCRP, as it is defined in the President's FY 1991

budget, is a sound approach toward reducing the scientific uncertainties associated with global change issues; (2) The Panel concluded that the investment in spaceborne observations, although comprising a majority of the proposed budget for a multi-agency plan, was a prudent one, given the pressing need to initiate long-term, global observations of fundamental environmental parameters; and (3) The FY 1991 Plan, including the new start for EOS, reflects the priorities established by the scientific community of this country over the past decade, and an unprecedented level of interagency coordination. It is also coincident with the goals and activities of the international community, through organized projects of the International Geosphere-Biosphere Program and the World Climate Research Program. In this sense, the EOS/Earth Probe initiative is one that has implications that reach farther than the efforts of a single agency; as a cornerstone of the USGCRP and IGBP, these new NASA endeavors hold the potential to put this country at the helm of a global effort for the common good that is now endorsed by all the major nations of the world. To this I should add that the EOS and Earth Probes that are described in the FY 1991 budget build upon a series of space-based research and monitoring activities that are already underway: a set of prerequisite missions sponsored by the NASA Office of Space Science and Applications that include UARS and TOPEX.

The first of my three points --- that the USGCRP and EOS/Earth Probes are a sound approach toward reducing uncertainties dealing with global change --- speaks to the mounting concerns expressed by

thinking people throughout this nation and in every other country regarding perceived and impending changes in the global environment. These changes include not only impending climatic warming, driven by alarming increases in greenhouse gases, but a growing list of others, including the depletion of stratospheric ozone, the destruction of tropical forests, loss of biological diversity, the quality and quantity of available water resources, sea-level rise, acid deposition, and a degradation of soils. They are all driven by the inexorable stresses that an increasing population and consequent development will continue to exert on the planetary environment. These concerns will not go away and can only increase. As responsible inhabitants of the globe, we have a duty to ourselves and to future generations to learn all we can about these and other environmental changes, in order to make the policy decisions that they will certainly require. The best investment we can make toward facing these impending changes is an investment in understanding them.

It is the stated goal of the U.S. Global Change Research Program to do just that. For seven years, since 1983, the NRC and the federal agencies that sponsor research in this country have been laying the plans for a responsible program that will address questions of the environment in a holistic way. It will do this through coordinated efforts of observation, focused process studies, and the development of reliable models that can be used for practical prediction. The FY 1991 budget for that program, expressed in the President's budget, includes a new start for EOS, as a cornerstone of the effort. The USGCRP is a package of focused research endeavors involving a dozen

agencies, with priorities arrived at through an unprecedented level of interagency collaboration among them.

The second point --- that a heavy initial investment in EOS/Earth Probes is appropriate and timely for this effort --- emphasizes the need to build for our future good a robust observing system that will track certain fundamental parameters of the planet to provide a reliable documentation of change. The data it will acquire and distribute will be usable by all, both as the measurements are taken and as a lasting record of change for future generations of scientists.

The state of the Earth is often described, I think appropriately, in medical terms. We are all concerned about the health of the global environment. We are asked as scientists to diagnose its condition, and to predict the very practical consequences of impending change. How irreversibly have we altered the environment through chemical changes in the atmosphere, land use, and modification of the soil? It is surely time that we mount an ongoing effort to monitor the vital signs of the Earth, and to put the planet in intensive care. EOS and associated Earth Probe missions will provide the spaceborne component of the U.S. plans to do that, and a data system that is capable of handling and distributing the vast amounts of information that will be acquired.

The third and final point expresses the context in which the Congress should consider both EOS and the USGCRP. These programs are the result of an unprecedented level of planning and review,

involving a broad community of scientists over the better part of a decade. The USGCRP and its international counterpart, the IGBP, have their roots in efforts of definition and planning that began in this country in 1983. At that time, as now, it was more than obvious that concerns of the global environment impinged not only on health and the quality of life, but on the economy and security of the country. It was also obvious, as now, that the scientific questions that were involved were of a nature that required something more than individual efforts, or programs within single agencies, or single countries acting on their own. Out of this grew the Global Change Research Program, whose stated goal is to establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system. It will do this by establishing an integrated, long-term program of documenting the Earth system --- its vital signs --- on a global scale; by conducting focused research that will improve our understanding of the system; and by developing integrated conceptual and predictive models that can be used in prediction.

These programs differ fundamentally from the efforts that most of us have pursued in the past in research in the Earth sciences in that they are directed at pressing problems of a practical nature, with the promise of direct inputs to the policy process. They differ in another way, in that they will commit the best and brightest scientists in an array of fields to work together toward these ends, for a term that reaches to the end of this decade and beyond.

The USGCRP also differs in that plans for its implementation, as described in the President's budget for FY 1991, represent a multi-agency consensus --- achieved through an unprecedented level of collaboration in the OSTP Committee on Earth and Environmental Sciences. The seven federal agencies that will support focused research in the program and who have worked together in defining the packaged FY 1991 budget include NASA, NSF, NOAA, DOE, EPA, DOI, and USDA.

I sincerely hope that Congress will recognize EOS and associated Earth Probes as scientists now see them: as linch-pins in the most ambitious, and I believe, most worthy goal that organized science has ever tackled. EOS and the USGCRP are investments not only in our knowledge of how the Earth works; through their ability to track the health and metabolism of the planet, they will also be in a position to sense significant changes as they occur. They address a set of very focused scientific questions that bear on the security and economic well-being of this nation, and the continued habitability of the globe.

The IGBP and the USGCRP are in 1991 at a critical juncture: the moment of launch, with a long and challenging voyage ahead. To reach their goal, it is very important that EOS and a program of Earth Probes, are aboard from the very start. The payloads, particularly for Earth Probe missions, can and will be adjusted as new information emerges. But the lead time required to mount spaceborne efforts of their complexity requires that they be started

now. This country can send no stronger signal to the world regarding our genuine concern for the global environment.

END

Reference:

The U.S. Global Change Research Program: An Assessment of FY 1991 Plans. National Research Council. National Academy Press, Washington, 1990. 107pp.

9/21/90

John A. Eddy
Office for Interdisciplinary Earth Studies
University Corporation for Atmospheric Research

Dr. John A. Eddy was born in Nebraska and educated at the U.S. Naval Academy and the University of Colorado. He has been associated with the National Center for Atmospheric Research (NCAR) and the University Corporation for Atmospheric Research (UCAR) since 1960. At present he is the Director of the UCAR Office for Interdisciplinary Earth Studies (OIES), founded in April of 1986 to "facilitate interdisciplinary research between the atmospheric sciences and adjacent fields of oceanography, geology, biology, hydrology, glaciology, and solar-terrestrial physics." The OIES supports the activities of interdisciplinary programs of research directed at problems of the global environment, including the U.S. Global Change Program and the International Geosphere-Biosphere Programme (IGBP). Dr. Eddy chaired the first U.S. Committee for the IGBP and has represented the U.S. on international planning commissions since the beginning of that program.

His own research is in solar physics, the history of solar behavior and of climate, and the history of astronomy, including archaeoastronomy. He is best known for his historical work on the Maunder Minimum of solar activity and its association with the Little Ice Age, and for his work, in archaeology, on the astronomical significance of stone Medicine Wheels left by the prehistoric Indians of the Western Plains. He is the author of over 100 scientific papers and books and has lectured at more than 125 universities and research institutions in the U.S. and abroad. He received the Arctowski award in Solar and Solar-Terrestrial Physics from the National Academy of Sciences in 1987. In 1988 he was made a Fellow of the American Association for the Advancement of Science.

Dr. Eddy serves on the Committee on Global Change of the U.S. National Academy of Sciences and on the Scientific Committee for the IGBP of the International Council of Scientific Unions. He also co-chairs with Hans Oeschger of Switzerland, the IGBP Coret Project on Past Global Changes. Since 1987 he has chaired the Panel on Climate and Global Change of the National Oceanic and Atmospheric Administration. He is a past president of the Commission on the History of Astronomy of the International Astronomical Union and of the Historical Astronomical Division of the American Astronomical Society.

Mr. NELSON. Thank you, Dr. Eddy.

Dr. Bishop?

Dr. BISHOP. Thank you, Mr. Chairman. I'll say also I'm pleased to be here today. I've enjoyed being here before and chatting with you on the record. I've prepared a statement for the record and I've submitted that to your staff. I'd like to summarize and make a few other points.

I served on the other panel as part of the review, the panel that looked specifically at EOS and its contribution. I'd like to make a few points and try to provide four simple answers to the four questions that Dr. Bromley asked of that panel.

The first couple of notes, in preamble. This orange-colored report that everybody has seen is, as the committee said, a snapshot. It's a picture of a program in development. The conclusions as the program develops will become more firm, issues will get resolved, or some changes might be indicated as the program goes along. I'd just like you to keep that in mind.

I'd like also in preamble just to give a kudo to NASA, and particularly in their support of our panel. Everything that our panel reported, I think, in that orange document was taken directly from or derived from reports and information that NASA provided us. NASA really opened its doors and its books and its staff time to us in that examination and showed us some things that were very preliminary, so that we could get a good idea of what was going on. We merely collected it between the two covers. I don't think we added very much to the analysis; perhaps a little bit, and we were, if anything, just one more of many reviews that both Dr. Fisk and Dr. Eddy have referred to.

Let me take the four questions in order then. The first question Dr. Bromley asked of our panel and we directly responded to was: Is EOS collecting the right set of environmental parameters? Our answer was simple. It was yes. It was a lengthy answer but it was unequivocal.

We had only one caveat about that, and that is that that answer has to be taken in the context of the overall measurement program that Dr. Eddy has referred to. It also has to be taken in the context of the entire space program that Dr. Fisk described, of all the nations and all the other programs.

I was afraid Dr. Eddy would use up all of the words like keystone and linchpin and flagship, and all of that. The agencies have called EOS the centerpiece of the U.S. Global Change Research Program. If it's not the centerpiece, it's certainly the essential piece, and Dr. Eddy has made that point already. It provides a global and a synoptic view that we just can't get any other way. But it can't do it all.

Take the second and third questions together, I'm afraid, because they're intertwined. Dr. Bromley asked us, Is the simultaneous measurement of many of these parameters important? And if so, how important? Then he asked us a related question: Is the current platform concept the optimal way to make those measurements, if the answer to the first question was yes?

We gave a lengthy answer. And I must say, in preamble, I began that review as a believer in a series of small satellites. I came out

of that review as a believer in the large platform, and I say that in preamble.

The simple answers are that simultaneity is important. It's very important. And some essential things can only be done with the simultaneous flight of a number of instruments. The science review teams and our panel identified 10 and we analyzed that, and we were convinced. Dr. Fisk used the word compelling in describing the argument. That was a word we used in our panel until the very final report. When some of the reviewers didn't share our enthusiasm for that particular word we changed it to strong. I still think that is a pretty positive statement about the need for simultaneity. That was for EOS-A.

There is also a lot of information available, and we studied it for EOS-B, and we came to the conclusion that the arguments were not as strong. I've studied those documents at some length, perhaps more than any of the other members of that panel, and my intuitive leap from that information is that I suspect when all is said and done the same arguments will hold for EOS-B. But I hold that conclusion still in abeyance until I see the rest of that analysis.

The second of the—the third question that Dr. Bromley asked: Is the platform concept the optimal way of doing it? If it's not optimal, it's certainly inevitable. That is my conclusion. And perhaps that makes it optimal.

For the science, the optimal package of the space system would be EOS in order to achieve the simultaneity of flight of those instruments, plus many specialized spacecraft to reach other orbits and to optimize the performance of certain sensors, plus a geosynchronous set of satellites in order to watch things happen rapidly on the meso-scale. Now, NASA is not coming forward with that kind of an optimal package, that top-of-the-line package as, I think it was Mr. Packard referred to it earlier, or maybe Mr. Sensenbrenner. They've come forward with what our panel concluded was probably the optimal compromise.

Some of the things that I've seen in the press would have you believe that we gave a very soft endorsement to the platform concept. I don't believe on rereading on the airplane here on the way to this hearing that that's the case. I think we gave a fairly resounding endorsement to at least the first series of platforms.

I'd like as a footnote to mention the small missions because that was an important part of our analysis. We looked at all the small missions and there are a couple of things I'd like to bring out right here. We endorse the Earth Probe lines. They're very important, and we agree with Dr. Fisk on that.

One thing we pointed out was that the synthetic aperture radar has been removed from the large platforms. We understand why. There were good engineering reasons for that. But our advice to NASA was keep it in the program. It has the capability potentially, as yet unproven but potentially, to make two important measurements that just cannot be made any other way; that is, soil moisture and biological mass in the canopy, and the only way those can be done on a regional or global basis is with something in space, and the only instrument we know of is the synthetic aperture radar. It's an important part of the program and it should be included.

There are some gaps that we pointed out in the report. Dr. Fisk has discussed some of those. I won't repeat that.

The fourth question Dr. Bromley asked us was: Is EOS-DIS the appropriate approach to answering the data management system? We think so. We gave a hearty endorsement to the two major features of the current approach, and that is, a lot of money invested in that—Dr. Fisk told you it is 60 percent for the data system and the science—and an early start on learning how to do the job. And we fully endorse all of that.

Our only—we offered some advice and pieces of advice, and I've outlined those in the prepared testimony. And our overarching advice to NASA was keep on with the current philosophy.

Finally, a couple of notes on data policies. It's something that we went into in the report. We took it as axiomatic that for the purposes of global change research, because it's our home planet and for all the reasons that Dr. Eddy just outlined, that a massive, unrestricted sharing of all of that data with everyone who could conceivably use it is important. And with that in mind, we commended NASA for its wide-open policies that it plans for EOS-DIS.

But there were some things that we pointed out that needed to be done. There needs to be a rescue mission for the archived satellite data that exist today, and we pointed that out in our document. We can't go back and collect data from 1978 again. If it's lost because the archives are not well maintained or if it's not available because it's too hard to get them out of the archives, it's just not useful, and it's irreplaceable.

Secondly, that data, as Dr. Fisk pointed out, provide some valuable early learning experience to get ready for the EOS era, and we pointed that out in our report.

As a last note, there are some problems in policies in the government, and as one who sat here before you in the past and argued for the current LANDSAT law and helped some of the staff on this committee put that together, I'd like to say it's probably not in the best interest of the country to have several of the provisions of that law. That law restricts NASA in how it may promulgate the data from EOS, and it also, because the data is expensive, restricts the access to the LANDSAT data itself, which is an important learning component and an important component during the EOS era. Both of those violate the principle that I espoused about massive unrestricted sharing of data for the common good.

We were not asked by Dr. Bromley whether EOS was a good idea; it was presented to us as a given. It is a good idea. In spite of not being asked, we had an opinion on that.

We support EOS. We support the general direction that it's taking, and we saw no reasons for any kind of dramatic change. We did offer in the report some minor suggestions, most of which NASA was already thinking about, for improvements in what appears to be the current direction of the program.

With that, I'll be happy to respond to questions.

[The prepared statement of Dr. Bishop follows:]

TESTIMONY

OF

DR. WILLIAM P. BISHOP
VICE PRESIDENT FOR RESEARCH
THE DESERT RESEARCH INSTITUTE
UNIVERSITY OF NEVADA SYSTEM

BEFORE
THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
OF THE
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

October 2, 1990

Mr. Chairman, I am pleased to be here today to present some views on NASA's Earth Observing System. I will henceforth refer to that System by its acronym "EOS."

On January 29th of this year, Dr. Alan Bromley asked the National Research Council to undertake a very rapid review of the U.S. Global Change Research Program, and in particular, NASA's EOS. I was asked by The Council to serve on the panel specifically set up to review the EOS. In what follows, I review some of the key points in the report of that panel.

Our review was of a program in progress. Thus both the reports we got from NASA and our findings must be considered a "snapshot" taken at this time. They will not be an accurate representation of either the program or our views some time in the future.

Furthermore, our picture of EOS was taken in the context of the U.S. Global Change Research Program and in the context of the other planned earth sensing space missions. It is only in the context of these programs that the potential of EOS can be judged.

In general, we found EOS to fit well into the context of both the USGCRP and the other space missions. The Federal agencies characterize EOS as the "centerpiece" of the USGCRP. We found that to be a justifiable view. However, as our panel mentioned in

several points in our report, we find a need for "traceability" from the scientific requirements of the scientific program to the specific measurements to be made from EOS and the decisions that are now being made and will be made in the course of the development of the program. We found that traceability up through an earlier EOS planning report, "From Pattern to Process: the Strategy of the Earth Observing system"; but we found a need for an update of that report and a continuing updating of that analysis throughout the program. Our advice to NASA is that "traceability" be updated soon and assiduously maintained throughout the program.

With the above as preamble, let me turn to the four specific questions that Dr. Bromley asked of the NRC.

COLLECTING THE RIGHT PARAMETERS?

> Does EOS collect the environmental parameters that are reflected in the USGCRP research priority framework and related policy issues described in "Our Changing Planet"?

We found that "EOS is being designed to measure environmental parameters from space that reflect the USGCRP framework and that will allow researchers to make major contributions . . ." This was not an easy finding to reach; there is no simple test. Developing that answer meant an item by item comparison with the scientific questions and the needs for measurements to develop answers for those questions.

We said throughout our report, and I must stress again, that not all of the important parameters are capable of measurement from space. To be measured from space, some material that enters into the process must reflect, emit or absorb radiation in a wavelength that will penetrate the intervening atmosphere. Further, that reflected, emitted or absorbed radiation must be somehow related (in intensity or wavelength) to the process of interest. Given that condition, we must then be able to build an appropriate sensor, place it in the proper orbit, and be sure that there is not some interference from some other ongoing process that will swamp the measurement of interest. And then we must be able to interpret the signal.

These are not simple constraints to meet. But in spite of that, many important parameters can be measured from space. A few can only be measured from space. And of the many, most can be measured

globally or regionally only from space. So, as our scientific view has expanded from the single geographic location to the larger scale, the view from space has grown in importance in spite of the difficulties.

In this context, we reviewed all of the main categories of scientific questions in the framework of the USGCRP. We produced a simplified discussion (pages 39-50 of the report) of how EOS will meet the needs for measurements in each category. Our discussion necessarily suffers from over-simplification, so it can only be used as an indicator of the overall impact of EOS in each area. In that higher level of abstraction, it is correct and useful.

We found that EOS contributes to all the areas of the USGCRP. That contribution ranges from critical to small. Importantly, the major contributions are in the areas of highest priority among the USGCRP areas. In short, as the report states, "the set of instruments under consideration for flight appears to be capable of providing a comprehensive set of measurements of high priority environmental parameters."

SIMULTANEOUS MEASUREMENTS NEEDED?

> EOS is premised on the assumption that it is essential to collect global data on various environmental parameters simultaneously. How important is data simultaneity to the ultimate quality of the data? Can the requirement of simultaneity be applied more narrowly than proposed?

Perhaps the most difficult of the questions addressed to the NRC was that of the need for simultaneous measurements. It was the most difficult because it was the least well documented at this point in the development of the program. Yet it is a crucial question in addressing the engineering configuration of the system.

Our panel found a "strong" argument for simultaneous measurements by ten of the instruments aimed at the highest priority scientific investigations under the USGCRP. It was an argument, or more properly, a set of inter-related arguments, that a number of us found quite compelling.

Four lines of analysis lend weight to the overall argument for the need for simultaneous measurements. First, to understand natural

processes usually requires the measurement of several parameters; where changes occur rapidly, these must be measured simultaneously. Second, interpreting the signal from one instrument often requires a correction from another instrument. Third, merging data streams from different times is usually difficult, and often impossible. Fourth, once some needed simultaneity points the way toward a larger space structure, the existence of that larger structure (or launch weight) simplifies the engineering and offers opportunity for further simultaneous measurement.

Our panel assessed all four lines of argument and the interactions among them. The four arguments are not independent. And they vary in strength and in the information we had available to document them. Part of the information on simultaneity for process studies was quite good, but it was limited to two of the USGCRP areas of emphasis (the two of highest priority). The information on space systems was also quite good, but limited to the several systems that NASA had analyzed. The data in the interplay of sets of instruments needed to interpret the signals was preliminary, though quite detailed. It was not, however, integrated. The information on integrating data streams was more an assertion of conventional wisdom by the panel than a carefully derived statement; the documentation was therefore not complete.

It is my assessment that the state of the information on each of these lines of argument is approximately what one would expect at this stage in the development of the EOS program. Remember what we saw and what we reported is a "snapshot" of a program under development.

The arguments are quite convincing for simultaneous flight of the set of ten instruments important to the two highest priority areas of the USGCRP. We found documentation for simultaneous flight of many pairs or trios of other instruments, but no complete and integrated argument for many of them being simultaneous. Thus, we conclude from arguments on process studies that there is not yet a conclusive case for simultaneous flight of a large payload for the other instruments.

We found many cogent arguments for simultaneous pairs of instruments to aid the interpretation of signals from one of them. Because the process of instrument selection and the development of algorithms for the derivation of geophysical parameters is still just beginning, these have not been fully integrated. My own estimate from studying the documents is that a case for simultaneous flight of other larger sets of instruments will arise

from the NASA process in due course, but it has not done so as yet. Our panel could not reach as strong a conclusion on this line of argument.

Once a case has been made for a number of instruments to be flown simultaneously, engineering considerations add considerable weight to the arguments. We covered many of these in the report, and I will not recite them again here. In general, however, having a large margin in launch weight, or a large platform onto which the instruments and support systems can be attached simplifies the engineering tasks substantially. Because launch vehicles come in specific sizes, not a continuum, a decision for a large set of instruments leads inexorably toward a large launch vehicle which makes it easier to accommodate the many and diverse instruments.

CURRENT PLATFORM CONCEPT CORRECT?

> Depending on the outcome of the question of simultaneity, are the EOS platforms, as currently configured, the optimal means for collecting data, or are there better alternatives that are more cost effective or timely? These alternatives could include, for example, smaller multiple platforms flying in formation or additional near-term precursor missions that are capable of flying subsets or preliminary versions of EOS instruments.

We found that one series of large platforms is required. This conclusion was based on the analysis of the two top priority research areas in the USGCRP. The current NASA platform concept is the correct one for at least the EOS-A series. The arguments are not as well articulated nor as compelling for the second series of large platforms. A series of more but smaller satellites could, at least for this "snapshot," be considered as well.

NASA must reasonably plan on what launch providers currently project for capabilities during the EOS period. Small launch vehicles in the Delta-II class cannot accommodate several of the key instruments at all. Intermediate vehicles in the class of the Atlas-IIAS cannot accommodate the set of instruments demanded by the two high-priority scientific areas. Thus, planning on currently projected capabilities, NASA is drawn inexorably to the Titan-IV.

We found no real alternative to this line of argument, even though the Titan-IV has more lift than really required. The only alternative we could devise would be for NASA to develop a dedicated launch capability for EOS alone and carry the full cost of that capability in the program budget.

Once the decision for Titan-IV is made, having that extra lift provides an ability for the engineers to simplify their task. This will allow such things as extra tape recorders, a traditionally weak system on orbit. It will allow easier accommodation of cooling for the instruments. It will allow easier arrangements for appropriate fields of view from the same platform. It will allow the use of less exotic materials. And so on. Based on this factor alone, were I the chief engineer on EOS, I would argue adamantly for the larger platform. As engineering difficulty is decreased, so also is the programmatic and financial risk decreased.

Because a reasonable time series of measurements is critical to the scientific progress in the USGCRP, EOS is planned for a 15-year lifetime. Because of this fact alone, our panel probed and analyzed the questions of reliability and continuity of the measurements. At one end of the scale -- that of backup capability for individual geophysical parameters -- we were pleased with the NASA approach. But that approach was in working documents that are not yet ready for publication. Near the other end of the scale -- that of replacement of a critical instrument -- we were concerned about an apparent lack of attention to the possibilities and a lack of a full analysis of alternatives. Our advice to NASA is to give the question of continuity of key measurements early and greater attention.

While necessarily incomplete at this time, NASA's analysis indicates that the large platform will provide the greatest reliability. This is based on design criteria rather than analysis of a point design (as is fitting at this stage of the program). Even though this cannot be a conclusive finding at this time, it does add one other argument for the current approach to the platforms.

Our panel recognized that costs will be a dominant factor in the decisions between design approaches. NASA's analysis, which the panel accepted, indicates that costs are minimized with the current design approach by a small margin. While cost thus adds another argument for the platforms as currently envisaged, it is not, in our minds, a conclusive one. (Nor does NASA claim it to be conclusive.)

SMALL MISSIONS

Because of the manner in which Dr. Bromley stated his third question about the platforms, and because of some early preferences on the part of our panel, we spent significant time debating small missions. Much of what we concluded is not directly relevant to the four questions. Nonetheless, several of the points are very important. Thus I offer them here under a general banner of "small missions."

First, there are some very important independent missions both approved and in the planning. At NASA, these include TOPEX, UARS, the scatterometer, and TOMS. All of these are fully justified and are not in any way superseded by EOS.

Secondly, there are several capabilities which would be very valuable during the interim before EOS that are not now approved. Significant among these is an ocean color instrument, very important for the Global Ocean Flux Study. Others include an advanced cavity radiometer to measure solar flux and radiation budget measurements like those flown on ERBE. These are not presently shown in the NASA planning. We believe they should be included in that planning.

Third, the Earth Probes line is very important. Not all instruments can be flown in the orbit of EOS. There are significant scientific payoffs from the Earth Probes line. Our panel commended NASA for including it in parallel to EOS, but worried that it might not being as well supported as it should be.

Fourth, and very importantly, one of the most significant instruments under consideration for EOS had to be removed from the platform for good and sound engineering reasons. That is the Synthetic Aperture Radar. While not fully proven for this purpose, this is the only instrument that holds out the promise of being able to derive global measurements of two key parameters -- soil moisture and vegetation mass. There is no feasible way to gain these measurements on global or regional scales from the ground, and no other way to make them from space. Only the SAR has a hope of success. We strongly recommend to NASA that the design for a separately flown SAR be completed forthwith and that it be included in the overall EOS program.

Fifth, our panel did not find as much integration in the planning of NASA and the other "space" agencies as we might have hoped.

Several of the above capabilities could be flown "piggy-back" on NOAA or DoD satellites. These include ERBE, an active cavity radiometer, and the ocean color instrument. Furthermore, NOAA has not taken full account of the possibilities for "pre-operational" status of some of the NASA instruments. Significant among these is the MODIS-N which appears to us to be a likely candidate to eventually replace the AVHRR on the current NOAA polar-orbiting satellites.

Finally, none of the small missions can in any way replace EOS. Even collectively, they cannot do so. EOS must be seen as the central part of a larger collection of space assets. The caution from our panel is to not overlook the special things that are being planned and are possible in addition to, and in conjunction with, EOS. And, of course, do not overlook what can and must be done from the ground, airplanes, ships, and other "platforms," and even with models.

EOSDIS APPROACH?

> Does the proposed EOS Data and Information System (EOSDIS) represent the appropriate approach to support this long-term data collection and modeling effort?

Our panel felt that "the preeminent challenge to global change research is the synthesis of diverse types of information from different sources." With this in mind, we applauded the two key ingredients of NASA's approach -- a substantial commitment of funds, and an early start on the EOSDIS.

Nevertheless, there is no precedent for the development of such a data and information system. It is a massive undertaking with little experience upon which to base it. But if successful, it alone could be the greatest contribution of EOS.

Because of, and perhaps in spite of, the lack of experience with such a system, our panel offered several themes of advice to NASA.

Allow the system to evolve. "NASA should not attempt to define total system specifications at the outset. . . EOSDIS should have a system architecture sufficiently flexible to accommodate [inevitable] changes and to implement them in an evolutionary manner." Judging from ongoing and just past changes in the computer and software areas, this would appear to me to be almost a mandatory feature of EOSDIS.

Allow for an immense diversity of data and information. EOSDIS must encourage and allow for data from many sources and data sets of diverse natures. "The objective should be an integrated national system for processing, distributing, archiving, and retrieving data and information about global change."

Make it as "distributed" as possible. "A distributed system should be pursued to take advantage of scientific expertise as well as computational facilities." Our panel "argues strongly against the development of a centralized system."

Involve others from the scientific community not now investigators in EOS. Because of the need for diversity, data from many sources, and decentralization, we found the need for further involvement of scientists studying global change no matter what the source of their funds or their data.

Prototype developments are important immediately. Because there are no design formulae for EOSDIS, the best approach is to gain experience in smaller attempts in similar directions. We offered an appendix full of ideas along these lines in the report.

We are pleased to find that NASA is generally moving in the directions indicated in our advice. We strongly urge them to continue in these directions and not succumb to the pressures for centralization and firm designs.

DATA POLICIES

We took it as axiomatic that the nature of the scientific endeavor and the potential urgency of finding some answers argue compellingly for a massive, unrestricted sharing of all global change data and information with all who would use it. In that regard, we were pleased to find the open data policies announced by NASA for EOSDIS.

However, we find some restrictions in both data policy and funding that could be damaging to the overall approach. Several of these are outside the scope of our study and outside the control of either NASA or the administration. Nonetheless, we touched on them in our report. Three of them are important enough to summarize in this hearing.

First, there is a significant historical record of remotely sensed data of the Earth from space. This record is difficult to access and not being adequately protected. This record exists at NOAA, the EROS Data Center of the USGS, the University of Wisconsin, and at NASA. Some of that data is in unreadable form. Almost all of it is stored on magnetic media which degrades with time and must be actively managed (i.e. re-recorded) to maintain it. All of these activities are underfunded. We run the risk of never being able to have access to that historical data if measures are not taken soon to both recover it and make it available. The investment is small (tens of millions of dollars) but the loss could be significant if measures are not taken.

Second, even though properly preserved, some of the data is virtually inaccessible. That inaccessibility is due again to lack of funding to make it available in the case of the data held by the agencies. In the case of Landsat, the barrier is simply cost -- the Landsat scenes are too expensive for most researchers.

Third, these satellite data sets are the prime candidate for early experience in preparation for EOSDIS. In several cases (e.g. Landsat and NOAA-AVHRR) they mimic in nature (though not in quality) the data that will be available from EOS. They could, if widely and easily available, provide invaluable experience in preparation for EOS. And some limited but significant scientific advances could be made with them in the interim.

Based on these observations, we concluded that three actions should be taken by policy makers. First, immediate steps should be taken to move existing data to secure storage media. Secondly, all research data should be made freely available (and inexpensive) to all researchers independent of sponsor or institution. Third, the restrictions on distribution of both Landsat and scientific data enacted in the Landsat law should be re-examined. Both Landsat and all research data should be freely available to encourage research in global change.

In summary, and in general, all data relevant to all phenomena under the theme of global change should be as widely disseminated as possible and as inexpensive as possible. These barriers to research in global change, barriers related to data policy and availability, should be removed as soon as possible.

SUMMARY

Our panel found EOS in general to be evolving in appropriate directions. Let me emphasize, we make this judgment from a "snapshot." However, with regard to a few issues -- significantly the second series of platforms, the question of continuity, and some issues having to do with historical data and data policy -- we offer some advice for specific directions of action or at least further analysis.

We have attempted to answer Dr. Bromley's questions directly, and the answers are generally "yes". We support EOS and see no reason for dramatic change in its directions.

DR. WILLIAM P. BISHOP

Ph.D.. from Ohio State University - Chemistry

Sandia Laboratories - Nuclear Testing Program 1969-1975

Nuclear Regulatory Commission - Nuclear Waste Management (Head of Program) 1975-1978

NASA - Deputy Director, Environmental Observations, 1978-1980

NASA - Deputy Director, Life Sciences, 1990-1984

NOAA - Deputy Assistant Administrator for Satellites, 1984-1987 (Included Landsat commercialization)

SAIC - Vice President (Civil Space), 1987-1989

Desert Research Institute (University of Nevada System) - 1989 - Present

Expertise (current):
Earth Sciences
Remote Sensing Programs
Institute Administration

Member of the NRC panel to Review EOS

Member, NRC Committee on Earth Studies of the Space Science Board

Mr. NELSON. Some of that restriction on LANDSAT was because of military implications, wasn't it?

Dr. BISHOP. No. The restrictions were mainly to give the commercial operator an opportunity to build his market.

Mr. NELSON. And you want to trace for us what has happened since that?

Dr. BISHOP. I'm not sure I'm the best person to do that, living out in the desert these days and watching from a distance. But it appears to me that the experiment that we all set out to do in commercializing has not turned out to be good for two reasons. One, we really didn't let it work the way we originally outlined it together, and we didn't put forward the budget to sustain it, and we didn't make a commitment to it such that people would step up to using it operationally, and so it hasn't become a self-sustainable operation.

And secondly, something has changed. As you pointed out, when we were all talking about things back when you joined the Congress global change was not a major issue. It is a major issue now. It wasn't even a major issue in 1983 and '84 when we were debating the LANDSAT law. Now that it is a major issue I think it's important to recognize that anything that restricts access to that kind of data is not in the general good.

Mr. NELSON. On the LANDSAT data, are we going to need to go back and change some of that law as we now approach this new era of concern and the global change?

Dr. BISHOP. I would certainly recommend it, sir.

Mr. NELSON. How—what has been the financial viability of those commercial operations on LANDSAT?

Dr. BISHOP. I have to plead ignorance of the details, but my sense is that the market has been growing at a rate not quite that predicted. You had three reports sent you by NOAA about a year ago that projected what the market would be and all of them came to the same conclusion, that it was not going to be totally self-sustainable. But perhaps the ground system could be, but it would never support the space assets.

That's not the major reason that we pointed out the problems with the law. The major reason was that for the purposes of global change research unrestricted access to the data and easy and inexpensive access to the data is important.

Mr. NELSON. NASA has indicated that LANDSAT data is required to support the science requirements of the EOS program. Has NASA concluded agreements with EOSAT for the provision of LANDSAT data?

Dr. BISHOP. I'm afraid I couldn't answer that. Perhaps Dr. Fisk could.

Mr. NELSON. Dr. Fisk?

Dr. FISK. Well, let me say it a different way. I mean, the problem that Dr. Bishop points out is in many ways an economic one. What we—the LANDSAT data is a very valuable resource on global change today. I mean, if you want to do deforestation or something like that you—I mean, there's a data source that you can use. We could practice with it in EOS-DIS, all those things things we talked about earlier. But the cost to researchers of accessing that data is prohibitive. You know, you can do simple little calculations that

says, you know, what would it cost you to buy the entire Earth, a scene of the entire Earth, which is what an EOS would give you say, if you do LANDSAT? If you bought it at commercial rates currently applicable to LANDSAT, it's like $50 million—one scene. And so, of course, assuming that's not how it would be applied if you tried to buy a scene, but nonetheless I think it's a demonstration of the costliness of the data in its commercial—

So we would very much like to be able to use this data because of its—what it gives us on global change, but it—we—in the current restrictions on its commercial availability that's simply not viable.

Mr. NELSON. Well, have you quantified the requirements for the LANDSAT data?

Dr. FISK. Well, I think that what you'd, what you'd want to do now is—let me, let me put this in two parts, in the pre-EOS part and the post-EOS part. In the pre-EOS part, I mean, we are looking for every piece of information about global change, give a baseline, and there it's going to be on specific research projects. If you deforestation in the Amazon Basin, for example, you would want to use a series of LANDSAT images. And so you could make a list, if you like. And I don't have one in my head, but you can make a list of the research projects that would be beneficial—for which LANDSAT data would be beneficial.

In the post-EOS era it's a little less clear because there we will instruments like the MODIS instruments on EOS, you know, are—and HIRIS, the high-resolution instruments, imaging spectrometer, you know, give you a lot more information than is available from a LANDSAT-type satellite. So there it's going to be a much more spotty use of the LANDSAT in the EOS era. But prior to EOS it is the existing database on land surface imagery.

Mr. NELSON. Is NASA going to be proposing a funding for the LANDSAT data?

Dr. FISK. I would not like to do that, if I can. Not unless there's a key to the Treasury here I haven't seen. What I would like to find a way is, however, within the funds that we have available to EOSDIS and the research that we're going to be able to sponsor that we have a way to access the LANDSAT data economically. I suspect there will have to be changes in the procedures, possibly in the law, to be able to do that effectively.

Mr. NELSON. Well, we've got about 5 minutes here.

EOSAT has indicated that it might explore volume discounts in its prices, but NASA hasn't indicated the volume that it needs. What's your intent?

Dr. FISK. Well, there's a lot of ongoing dialogue, particularly in the administration in the Committee on Earth and Environmental Studies—the CES—that, on the role of LANDSAT.

I'm a little puzzled by the statement that we don't indicate volume because I think there is a lot of dialogue to that extent.

Mr. NELSON. Last December, we—go ahead.

Dr. FISK. The answer is 15,000 images per year.

Mr. NELSON. Last December, the committee was informed that the administration had decided to go ahead with LANDSAT VI and launching in about '96. Then a decision on LANDSAT VII was to be made during the EOS time frame. Now that we are coming up 10 months later we still don't have a decision.

If the High-Resolution Imaging Spectrometer is delayed, would it make sense to make a commitment to LANDSAT VII so that we can be assured of having a high-resolution land imagery without any interruption?

Dr. FISK. I think that's an issue we would have to look at. There is some substantial differences that—I mean it's not easy for me to give a quick answer to that for the following kinds of reasons. The EOS-A platform is an early afternoon platform. That means crossing time, when it makes its measurements is in the early afternoon. You choose that orbit for lots of reasons: maximum Sun angle—or minimum Sun angle, you know, vertical Sun; maximum biological stress. I mean there are all sorts of reasons for doing so. The LANDSATs have historically been 9:30 in the morning crossing times and for other reasons. So there are trades that are made there that are a little technical for me to try and make a quick answer to that. We can try and give you one for the record.

Mr. NELSON. Okay. Will this spectrometer HIRIS—if that's the acronym—

Dr. FISK. That's it.

Mr. NELSON. Will it be on the first platform?

Dr. FISK. I will tell you in 2-1/2 weeks. We're in the final confirmation.

Mr. NELSON. Okay. Mr. Hall, we have an opening statement from you that will be part of the record, and we want to submit additional questions, any of the members, for the record.

Mr. Hall?

Mr. HALL. Thank you, Mr. Chairman.

We had a joint hearing with the Space Committee and my committee, International Scientific Cooperation Subcommittee, in July, and at that time we concentrated, for my part, particularly on the international aspect of the mission, and we asked several questions of NASA that we have not yet received the response to. And I know I don't have time to extract those responses, but would ask you to check on those, please, and get them to us. It would be very helpful to us.

And I yield back my time. We have to go vote, Mr. Chairman.

Mr. NELSON. In just a moment.

We feel like this has been a productive hearing, and you will notice by the questions today that this subcommittee doesn't have any reservations about supporting this program. We think it's vital to the long-term survival as a species on Planet Earth, and it's part of our responsibility to be good stewards of this delicate ecosystem called Planet Earth.

What we're concerned with is that we make the best use of limited resources as we plan the program. So we're going to look forward to continuing to examine this over the course of time.

You all are very kind to come all the way from Las Vegas and Boulder to be with us. We appreciate your work and your expertise in testifying today. Thank you, and have a good day.

[Whereupon, at 4:04 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

APPENDIX

**ANSWERS TO QUESTIONS FOR THE RECORD
SUBMITTED BY THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
TO DR. WILLIAM BISHOP**

1. **One of the main concerns of the Subcommittee is how well the EOS architecture addresses the scientific objectives of the EOS program.**

   a. Did NASA give your panel a documented, prioritized set of specific scientific objectives to be satisfied by the EOS program?

1a. Yes. NASA offered the same set of prioritized scientific objectives used by the Committee On Earth Sciences in its several reports accompanying the President's budgets over the last several years. As with all the other agencies in the Global Change Research Program, these are NASA's agreed to set of scientific objectives in priority order.

   b. If so, did your committee agree with the priorities and with NASA's assessment of EOS's ability to satisfy them?

1b. Our committee did not specifically assess our agreement with this set of priorities. However, the committee on Global Change of The National Research Council as reviewed the CES report on two successive years and give at least preliminary agreement with the priorities. Our panel merely accepted the judgment of that previous review.

   c. Had the set of prioritized scientific objectives been peer-reviewed?

1c. Since the priorities of the committee on Earth Sciences had been reviewed by the EOS scientific committees and the NRC, I would have to conclude that these prioritized scientific objectives have had a peer review.

2. **If we can't be assured of having sufficient funding over the next several years to carry out EOS, but still want to use space technology to do important environmental research and monitoring, what do you recommend be done?**

2. I would first recommend continuing the current Earth Observing space programs (including those at NASA, NOAA, the DOD and our cooperative programs with other countries). Second would be to run the "rescue mission" on the existing archives of space remote sensing data. Those archives are irreplaceable and can be quite useful in preparing for EOS. Further, some significant scientific effort can be done with them, but not nearly

of the same magnitude or quality as that which will be possible with EOS. Third, the problems with the Landsat law should be fixed. Fourth, the largest challenge with all of the EOS program is clearly the EOS-DIS. The pilot projects and the overall development of that program should be continued at some appropriate level no matter what else is done. Fifth, the scientific teams that have been assembled around each of the major (or even minor) EOS instruments ought to be supported. Further, they should be supported at a level adequate to make some progress in preparation for EOS. If these five (5) things are done, then the investment and the momentum surrounding the current EOS planning can continue.

However, you asked me a speculative question. There is an alternative answer. I believe that the goals of EOS, and more broadly the U. S. Global Change Research Program, are important enough that they should take priority over many other things that this committee and the Congress have before them for funding. There is no real alternative to an EOS program. As I said earlier, it is the "optimal compromise" toward reaching the scientific goals of the U. S. Global Change Research Program.

3. **The NRC report stated on page 39 that "the technology of remote sensing is also likely to change over the life of the program...Currently, the program contains no process that would enable it to evolve in response to new scientific understanding of technological developments."**

a. How serious a concern is this lack of an evolutionary capability for a planned 15-year observational mission?

3a. Our concern was not over a "lack of an evolutionary capability", but rather a concern over the lack of specific planning for that evolution. We pointed out in our report that the planning for common interfaces should make evolution more easy than it has been in many space missions of the past. Nonetheless, NASA has put in place no process to assure that this engineering capability can be properly exploited to allow the system to evolve. I do not believe that this is a "serious concern" because the "fix" for the concern is simply to establish such a process.

b. What would the NRC panel recommend be done?

3b. The panel would recommend and did recommend that a process for evolving the EOS system be put into place by NASA. That could take many forms. It could be a yearly review of new technologies; it could be a yearly review

of the science and the needs for new measurements; it could be a yearly review of the science and the intention to drop all the measurements that are not proving productive; or it could be all of these and more. At any time in the program, a new capability could be made available for flight in about five years. All our panel would recommend is that NASA put in place the process by which these scientific and technological advances can be exploited.

4. The NRC report identifies two missions that are not currently provided for in current NASA plans:

1. A follow-on the Earth Radiation Budget Experiment (ERBE) after the French/Soviet SCARAB mission files.

2. A synthetic aperture radar (SAR)

a. How important are these experiments relative to EOS-A? Should EOS-A be delayed, if necessary, to allow these missions to be conducted?

4a. These experiments should in no way supercede or replace EOS-A. EOS-A should not be delayed to make these missions possible. However, as I said earlier, the synthetic aperture radar (SAR) potentially provides measurements that can be made in no other way. It should be included within the overall EOS program.

b. On what do you base your conclusions?

4b. I base my conclusions on a fairly simple rationale. With regards to the Earth Radiation Budget, the magnitude of the information to be provided relative to EOS-A is very small. The Earth Radiation Budget experiment has been done, the analysis of that data is not yet even complete. Our report merely indicated that for a relatively modest investment, the experiment could be continued until such time as EOS-A could be flown.

The synthetic aperture radar (SAR) is a different story. It is and should be considered an integral part of EOS. That is what our report stated. It is not something to be traded against EOS-A. It is an important component of the Mission to Planet Earth and an important component of EOS in general. Its removal from the EOS-A platform was for good and sound engineering reasons; but its contribution to EOS is potentially enormous. By the synthetic aperture radar (SAR) and only by the synthetic aperture radar (SAR) do we have some chance of observing soil moisture and canopy biomass on a global or even regional scale. There is no feasible way to do that from the ground. But soil moisture and canopy biomass are of

only modest utility without the other measurements that are being made from of EOS-A.

In summary, the Earth Radiation Budget Experiment (ERBE) and the synthetic aperture radar (SAR) are not things to be traded against EOS-A, they are important adjulance to the mission that EOS-A represents.

5. **One of the major issues surrounding the EOS initiative is the belief on the part of a number of serious researchers that we do not yet know enough about the key parameters involved in Global Change to determine which ones are critical in determining the rate and magnitude of potential climatic changes (e.g., the role of sulfur products in the atmosphere). They do not argue that we will not get useful data from EOS--just that the EOS program is premature; they argue that the funds spent on EOS would be better directed first to space missions aimed at increasing our understanding of what the key parameters are. Only after we better understand the determinants of environmental change should we attempt to launch long-term monitoring satellites like the EOS series. Do you agree or disagree? Why?**

5. I disagree and very strongly. I disagree because the question as framed inadequately or even incorrectly characterizes EOS. I also disagree for what may be a more fundamental and philosophical reason.

First, EOS is not simply a "long term monitoring" satellite. EOS is designed to explore the scientific boundaries of what we know about the earth as a system. It is not the only way to explore those boundaries, but, because of its breath, it explores more of those boundaries than any other approach with which I am familiar. All the other approaches are much more narrow, exploring some single aspect of the scientific understanding of the earth. This is not to say that those other approaches are ill-conceived, but they are simply focused studies limited in their scope. As Dr. Eddy testified, EOS is important because of the urgency of the changes in our planetary system-our very life support system-that we press on with something like the Mission to Planet Earth.

Second, and more philosophically, the cry for prudence and caution in exploring scientific frontiers always smacks in my mind of vested interests protecting their own turf. One can argue that all scientific experiments are premature; that no hypothesis is succinctly or positively defined enough to warrant the expense of the experiment. I'm tempted to say, "Me thinks the critics (of EOS) protesteth too much."

**ANSWERS TO QUESTIONS FOR THE RECORD
SUBMITTED BY THE HONORABLE RALPH HALL
TO DR. WILLIAM BISHOP**

1. Given your examination of NASA's plans for EOS and EOS-DIS, do you think the challenge can be met by any existing private sector management system?

1. No sir, I do not think that the challenge can be met by any existing private sector management system. My belief springs from two simple principles. First, there is no profit in it. Second, we are talking about something that has to do with the public good. That is usually a government function.

That is not to say that the management expertise in the private sector is not applicable to the goals of EOS. In fact, many of the management techniques that are used by the government agencies, such as NASA, are derived from the experiences in the private sector. But I do not see a private sector analog for the things that need to be done under the banner of Global Change Research and EOS.

2. If U.S. business wanted to use data from the EOS-DIS to make its operation more environmentally sound, would it pay the same price as a public sector research institution?

2. Sir, as I said in my prepared testimony and in my more informal remarks before the committee, our panel took a position in which I sincerely believe. That is that a free and open exchange of all the Global Change Research data is in the best interest of humankind. I believe that any U. S. business (for whatever motivation, whether it be making its operation more environmentally sound or making a larger profit) should be given access to that data at the same price as any other party (which should be minimal). Making use of that environmental data for whatever purpose will only increase our understanding of how the planet operates. It is in the public good to see that all such uses are encouraged and all of the benefits to be accrued by increased understanding are realized. Let me say it again, as strongly as I possibly can, an open, unfettered, inexpensive (perhaps even costless) exchange of all this environmental data is in the best interest of all of us.

Responses to written questions submitted by Chrm. Nelson resulting from the October 2, 1990, hearing.

QUESTION 1:

The management of the EOS program will be a major undertaking. Both the spacecraft component and the data management component have interfaces with other government agencies, with the research and applications communities, and with international and foreign organizations.

a. How do you respond to the view that the EOS program is too large, complex, and important, and has too many interfaces with external organizations for its management to be relegated to a Division-level status within the Office of Space Science and Applications? Should there be a program office reporting directly to the NASA Administrator? Why or why not?

b. How do you respond to proposals that EOS be taken out of NASA completely and be managed by a national program office that could coordinate the multiple interfaces (users, other agencies, foreign?

ANSWER 1a:

NASA has the demonstrated capability to manage and coordinate the Earth Observing System (EOS) program. In planning for this program, we focused not only on hardware issues but also on the necessary national and international coordination. From the beginning, planning for EOS has actively involved input from the global science community, in an effort to design a system to make observations and produce data which are timely, accessible, and critical to a better understanding of the Earth.

NASA has a long-standing program of conducting cooperative Earth science observations and research programs with other Federal agencies, foreign governments, and national and international science organizations. These interfaces are well established and have yielded a host of successful scientific and programmatic results. For example, we have coordinated numerous research and flight program efforts with the National Oceanic and Atmospheric Administration (NOAA), including successful development of the Landsat and geostationary and polar meteorological systems. We have conducted extensive research efforts with other agencies and industry in areas such as polar ozone research. We have developed productive working relationships with national science organizations, including a long-standing relationship with the National Academy of Sciences.

We have worked with other nations on developing important joint programs, such as the Ocean Topography Experiment (TOPEX/POSEIDON) mission with France and the flight of a Total Ozone Mapping Spectrometer (TOMS) instrument on a Soviet spacecraft, which are significant precursors to EOS. We have been active participants in international scientific organizations such as the Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organization (WMO), and

the United Nations Environmental Programme to conduct research programs such as the International Geosphere-Biosphere Program (IGBP) and the World Climate Research Program (WCRP).

We have made full use of this experience in our overall planning for the EOS program, soliciting input and guidance from numerous sources. EOS has been carefully coordinated through the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committee on Earth and Environmental Sciences (CEES), in an effort to insure that it fulfills the space observation requirements of the U.S. Global Change Research Program (USGCRP). Our plans for EOS have responded to the science objectives of the USGCRP, agreed to by the agencies which make up the CEES through an unprecedented process of open communication, discussion, and cooperation. The CEES offers an excellent forum for national coordination needed to enable a successful global change research program. USGCRP science objectives, which guide the planning for the EOS instrument selection and science planning, have similarly been coordinated with international science groups such as the IPCC, WMO, and UNEP. In addition, specific planning for the international polar platform program has occurred through the Earth Observations International Coordinating Working Group (EO-ICWG) and the Committee on Earth Observations Satellites (CEOS).

With respect to program management, EOS is fundamentally an Earth science program. As such, it should be managed, both at Headquarters and at the Goddard Space Flight Center (GSFC), by those most familiar with the issues and management of Earth science missions. NASA has designed a logical and practical organization to direct the program, within the overall guidance of the Office of Space Science and Applications. Moreover, because EOS is only an element of the larger space science effort associated with Mission to Planet Earth, it is important to keep overall coordination of the program within the Earth Science and Applications Division.

Senior NASA and OSSA managers plan to manage the development of EOS with a high level of scrutiny and oversight. The program management structure for EOS has been designed to maximize visibility into several levels of detail, including science, observatories, instruments, and ground operations (including the data system). In addition to analysis at these levels, all aspects of EOS planning and development are subject to ongoing assessments by several levels of project and program management at regular intervals.

b. Given our experience and demonstrated capability in developing space based observatories, NASA is the appropriate agency to manage the EOS program. The process and interfaces needed to conduct this program, both within NASA, the Federal government, and the international community, are well established. Design of another agency or coordinating body to manage a small portion of the U.S. space program would be counterproductive to the efficient and effective use of the national resources currently in place and managed by NASA. A new program office outside of NASA would serve only to add an

additional layer of management to the EOS effort, and would likely cause unwarranted schedule delays.

NASA's long history of managing space development and science programs in Earth science and other disciplines involve the same users, agencies, and foreign entities with which we will need to coordinate the EOS program. Though the EOS program may be a larger and more significant undertaking, a clear process is currently in place to allow us to manage this mission. This experience in planning, developing, and integrating complex science missions, such as NIMBUS and the Earth Radiation Budget Experiment (ERBE) in the 1970's and the Upper Atmosphere Research Satellite (UARS) and TOPEX missions in the 1980's and 1990's, gives NASA the critical background to manage a program of the size and scope of EOS. NASA has the facilities, the personnel, and the recognized leadership role in the area of space and Earth science to manage the EOS program.

QUESTION 2:

The contract for EOSDIS will be one of the most significant NASA information system contracts.

a. What is the anticipated size of the EOS-DIS contract?

b. According to POP 90-1, when are the intended EOSDIS RFP release and contract award dates? What is the current schedule? If either has been delayed, what are the reasons?

c. Can you assure the Subcommittee that there will be no further delay in the contract award?

d. What is the latest the contract can be awarded and still meet the intended 1994 EOSDIS on-line date?

e. Will the EOSDIS be a competitive procurement?

ANSWER 2a:

The specific amounts required for development of the EOS Data and Information System (EOSDIS) Core System will depend on the details of proposals which are submitted and selected. All such information is currently considered procurement sensitive.

b. The Request for Information (RFI) for the EOSDIS Core System contract was released on schedule in October 1990. Based on the responses and inquiries concerning this release, the Request for Proposal (RFP) is expected to be released in February 1991. Based on review of these submissions, and the inclusion of the technical and programmatic requirements outlined in the RFP, a full, formal contract award is expected by August 1992.

c. Meeting the current schedule for the EOSDIS Core System contract award depends on consistent funding for the EOS program.

d. The 1994 on-line schedule refers to the EOSDIS Version 0 system, which would be a prototype for early use by researchers.

The early EOSDIS is intended as a working prototype system with operational elements, including some fully functional Distributed Active Archive Centers (DAACs), all EOS-A related Science Computing Facilities, a fully functional EOSDIS internal network, and access to EOSDIS from general scientific networks. This prototype system would come on line in 1994 to support the analysis of existing Earth science data, to provide support for the data generated by early elements of Mission to Planet Earth, and to allow scientists and system engineers to test the system prototype architecture. It is not intended as an operational system.

The EOSDIS Core System Contract will support development of the core EOSDIS operational system, beginning with the Version 1 system scheduled to be on-line in 1996. This contract focuses significantly on the acquisition and development of hardware and software needed for an operational system. While several of the deliverable elements of the Version 0 prototype system (which focuses primarily on improved networking and data analysis) planned to be on-line in 1994 are not dependent on the EOS Core System Contract, development of the EOSDIS Core System does build on the experience from the prototype system before coming on-line in 1996. For the program to meet this fully operational milestone, the early activities would need to be fully funded and the EOSDIS contract would need to be awarded before the end of FY 1992.

e. Yes. The Request for Information (RFI) for the EOSDIS Core System contract was released in October 1990, with the Request for Proposal (RFP) expected for release in February 1991. A full, formal contract award is expected by August 1992.

QUESTION 3:

NASA currently plans to have the EOSDIS operational well before the launch of the first EOS platform. In fact, it plans to have the processing, archiving, and distribution of data through EOSDIS on line by 1994. However, the NRC report states that "the intended scope of the [EOSDIS] system far exceeds that of any existing civilian data management system."

a. How much do you plan to spend on EOSDIS in FY 1992 and FY 1993?

b. The contract for EOSDIS is not scheduled to be awarded until 1992, and EOSDIS is to be operational in 1994. Are there any previous data management development programs that you are using as a basis for your development schedule? What are they? If not, what is the basis of your estimate?

c. What do you consider to be the highest risk items in the EOSDIS development?

d. If you do not receive the desired amount of funding, will you decrease the capabilities of the EOSDIS or delay its operational date beyond 1994? On what do you base your choice?

e. Since EOSDIS is intended to support both EOS and non-EOS data collection and distribution (including for near-term missions), would you attempt to maintain funding for EOSDIS even if it meant delaying the EOS spacecraft development? Why or why not?

ANSWER 3a:

Specific funding plans for FY 1992 and FY 1993 are dependent upon OMB and Presidential approval of the NASA budget request currently under consideration. Figures for FY 1992 will be available upon submission of the President's budget in early 1991.

b. The EOSDIS Core System contract scheduled for award in 1992 will primarily support development of the operational Version 1 EOSDIS. This operational version is scheduled to come on-line in 1996. The prototype Version 0 data system, scheduled to come on-line in 1994, will support early science operations and contribute to the final design of the Version 1 system.

The overall development of the EOSDIS is based on extensive NASA experience with data systems and technology. While the size of EOSDIS clearly makes it the largest data system which NASA has ever constructed, its difference is primarily in scope and approach, rather than in specific means of implementation. We have learned much from our design of earlier space science data systems, in terms of user interfaces, networking, processing, and data storage and distribution.

In recent years we have taken some significant steps to improve our handling of data resources, evolutionary improvements which will guide our development of EOSDIS. For example, NASA has a significant on-going effort to improve the way we process and handle data from previous and upcoming missions to ensure that it is practically available to the science community. This effort focuses on converting existing data sets, from both NASA and NOAA, onto optical disks from magnetic tapes. This data conversion will allow NASA to calibrate and improve these data sets, to produce geophysical data products and to distribute them to the scientific community for research use. Notable data sets such as the Coastal Zone Color Scanner (CZCS), Advanced Very High-Resolution Radiometer (AVHRR), and the Geostationary Operational Environmental Satellites (GOES) are among those currently in process. Data processing for systems in the Mission to Planet Earth era are being tailored to feed into the early operations of the EOSDIS, so that use of that data will be rapidly available.

In addition, as forerunners of the EOSDIS, NASA developed several pilot data systems (including the NASA Climate Data System, the NASA Ocean Data System, and the Pilot Land Data System) to test new concepts for data archival distribution. These concepts include improved network links to users, interactive user interfaces to the archives, on-line directories and inventories, and new optical media such as compact disk read-only memory (CD-ROM) and optical disk technology to improve data accessibility. NASA is bringing existing agency Earth science

data sets under the management of these pilot data systems, with better documentation, consistent inventories, and scientific oversight by advisory panels. Moreover, to aid in the use of these new systems, NASA developed an on-line Master Directory which includes searchable listings of all Earth science data holdings.

Our development schedule is based on the need for a logical progression of hardware and software development, along with the time and experience required to provide the needed user interfaces. EOSDIS is designed to be an interactive, evolutionary system, expanding upon existing structures and interfaces. The schedule for EOSDIS development, while driven by the ultimate need to support the launch of the first EOS platform, is designed to support science research users as early as practically possible and to use early operations as the basis for evolutionary improvements to the system in successive versions. Thus, the prototype Version 0 EOSDIS will build upon existing systems (such as the NASA Climate Data System), use existing technology to network the Distributed Active Archive Centers (DAACs), and provide improved access to, and new products from, key global change data through pathfinder data sets (from previous missions). Experience with this prototype system will give researchers and systems analysts an opportunity to make changes and additions required before the first operational system (Version 1) comes on line in 1996. Similarly, successive versions will build upon prior experience to provide for a steady evolution of the system.

c. As often is the case with major space system development, the primary challenge to the development of the EOSDIS is the successful management of the interfaces between the system and its users. The challenge of this development is the design and execution of a system which will have the capacity and capability to support thousands of Earth science investigators, worldwide, who will regularly access the system. We need to expand the capacity we have in our current NASA data systems to support this increased number of researchers, to make the data in the system more accessible for their analysis, and to do so in a more timely fashion.

While this is clearly a challenging goal, NASA believes that it can be accomplished. Evolutionary development of the EOSDIS includes time for researchers and systems engineers to gain experience with the system and to suggest any changes required to support science and user requirements. This approach includes the development of a prototype system, followed by subsequent operational versions. Though EOSDIS will make use of new technology as it evolves, the development schedule is such that system success does not depend on the development of such technology but simply is flexible enough to incorporate it once it is tested and approved. The program includes plans to upgrade EOSDIS hardware every five years to reflect the evolutionary state of technology.

Successful development of the EOSDIS depends on a constant funding profile, along with timely and orderly execution of the

procurement process. This will permit the evolutionary plan for the system to be fully implemented, on a schedule designed to support applications by the Earth science community and the launch of the EOS platforms.

d. The Version 0 EOSDIS, scheduled to be on-line in 1994, is a prototype system rather than an operational one. While it will have some operational elements, the processing of existing data through the system will be designed both to expand the use of these data sets and to test the prototype system for design and software modifications. Based on these efforts, subsequent operational versions will be modified to incorporate the lessons learned from Version 0. Since elements of subsequent versions depend on the testing of Version 0 and the experience from its use, any delay in funding for early elements of the EOSDIS would likely delay the development program for the later versions.

NASA is committed to provide the necessary support to have the Version 0 prototype system on-line in 1994, given its importance to further EOSDIS development and to the science processing of existing data sets. If it becomes necessary to accommodate funding reductions, we would delay subsequent versions of EOSDIS to insure that we meet this Version 0 deadline. However, if there are substantial funding constraints, we would have to seriously consider a slip in all EOSDIS milestones, including those associated with Version 0 (prototype) development.

e. Funding for early development of the EOSDIS, and the support it will provide to the science elements of the EOS program, is the highest priority for the EOS program. The expanded availability and analysis of current and near-term data sets is an important component to achieve a better understanding of global change. Moreover, the orderly and timely development of the EOSDIS is critical to insuring that data capabilities are fully operational when the EOS platforms are launched. In the event of funding reductions, we plan to maintain maximum possible support to the early development of EOSDIS, even if delays in spacecraft development are required.

QUESTION 4:

In the response to one of the questions submitted following the February 27, 1990, authorization hearing, you indicate that the EOSDIS critical design review will occur in the first half of FY 1995. In another response, you state that the EOSDIS "will be brought on-line by 1994." Can you clarify the apparent contradiction.

ANSWER 4:

The EOSDIS prototype system (Version 0) is scheduled for on-line operation in 1994, while the operational system (Version 1) is planned to be in place by 1996. This evolutionary development is designed to insure that experience with each version is incorporated into development of subsequent versions. This approach is also designed to incorporate any changes in technological or scientific understanding into the system. As a

result, there will be a Critical Design Review (CDR) for each version of the EOSDIS. In addition, the Version 1 CDR will be conducted in the same timeframe as the Version 0 Performance Review, to insure that Version 1 development includes any lessons learned from earlier efforts.

QUESTION 5:

The EOS Program is predicated on certain minimum sets of instruments flying on the same platform to satisfy science objectives.

a. Does the EOS program have a documented, peer-reviewed set of specific and prioritized science objectives? If so, when was it completed? Please provide a copy to the Subcommittee.

b. Have you investigated any "fallback" missions in case funding or technical difficulties force you to fly smaller complements of sensors? If not, why not?

c. Have you determined quantitatively the drop-off in realization of the EOS science objectives that would result from the deletion of any given instrument? If not, do you have any plans to do so?

ANSWER 5a:

In the course of developing the plans for the Earth Observing System, NASA has been guided by the advice of the NASA Advisory Committee and the National Academy of Sciences and by numerous reviews by scientists throughout the Earth science community. Over the last eight years, NASA and the scientific community have extensively reviewed the science requirements and design of EOS, the choice of instruments for the platforms, and the approach for conducting scientific research and data processing.

Mission to Planet Earth, of which EOS is a critical part, is intended and designed as the space component of the U.S. Global Change Research Program (USGCRP). The science objectives and priorities (detailed in the "Our Changing Planet: The FY 1990 U.S. Global Change Research Plan) of the USGCRP were reached through discussions within the interagency Committee on Earth and Environmental Sciences (CEES), and reviewed extensively by independent scientific and technical organizations, including a recent review by the National Research Council (August 1990). These science objectives and priorities have been adopted by the EOS Payload Advisory Panel as the basis for mission science and instrument selection for the EOS program. Definition of more specific scientific objectives is underway through the work of the EOS Investigator Working Group and through the planning for the 29 EOS Interdisciplinary investigations.

b. NASA has examined a number of potential options for dealing with difficulties in EOS sensor development. We have conducted extensive definition studies for each proposed EOS instrument, giving us a thorough understanding of the challenges and difficulties associated with sensor development and, thus, the

feasibility of including specific instruments in the payload complement for one of the two EOS platforms. The EOS-A payload confirmation, which is expected in November 1990, will reflect these considerations.

Most of the proposed EOS instruments have evolved from other instruments which have been tested extensively and flown aboard satellites, the Shuttle, or NASA research aircraft. While some of these sensors will be among the most sophisticated NASA has ever flown, none of them requires NASA to formulate a new technology as a part of their development.

The science community has consistently emphasized that a long-term, comprehensive set of simultaneous observations is the key to the success of the EOS program, and is necessary for EOS to fulfill the science requirements of the U.S. Global Change Research Program. NASA designed the polar orbiting platforms to provide the capability for such simultaneous observations by a coordinated suite of instruments. The recent National Research Council (NRC) report on the U.S. Global Change Research Program strongly endorsed this approach for the EOS-A platform series, while asking NASA to look more closely at the requirements for the EOS-B series. NASA does not believe that flying EOS-A instruments on a series of smaller satellites would achieve the scientific objectives of the USGCRP and the EOS program. We are currently reviewing the requirements for the EOS-B platform series, examining whether the science objectives could be met by flying the instruments aboard smaller platforms.

c. It is difficult to "quantify" such losses because of the synergistic nature of the EOS payloads. The loss of data and understanding would exceed that of each individual instrument removed. In such a case, the validity and clarity of the remaining observations would also be lessened, either because comparison measurements would no longer be made or because instruments measuring the intervening atmosphere would no longer be included. Clearly, with the EOS goal of understanding the Earth as an integrated and coupled system, we are striving for the most complete scientific payload which can reasonably be supported.

In the extensive planning for the EOS program, and through the process of instrument confirmation for the EOS-A platform series, NASA, together with the science community, has carefully examined various combinations of instruments and what level of detail and scientific accuracy each would provide. We have made estimates of the science tradeoffs involved with each of these combinations. These tradeoffs, though not necessarily quantifiable, have been calculated, and depend on the instruments involved and their interactions with the remaining payload.

QUESTION 6:

The sensors to be flown on the EOS-A platform have an impact on many aspects of the EOS mission design.

a. What sensors have the highest technical risk associated with

their development?

b. What are your contingency plans if a sensor encounters development difficulties that threaten to delay delivery of the EOS platform?

c. Are there any sensors you consider critical to the mission -- i.e., such that you would not fly the platform if the sensor was not available?

ANSWER 6a:

Most of the prototypes for proposed EOS instruments have been tested, in some form, on previous satellite or aircraft flights. For example, the Airborne Visible/Infrared Imaging Spectrometer (AVRIS) - a prototype for data reduction, band width, and science for imaging spectrometers - has been developed and flown many times aboard the ER-2 aircraft over the past year. NASA will continue to fly this instrument in order to better understand the data which will be generated by the Moderate- Resolution Imaging Spectrometer (MODIS) and High-Resolution Imaging Spectrometer (HIRIS) instruments. Even though there is heritage with AVRIS and other surface imagers, these imaging instruments proposed for EOS represent significant technical challenge to the program, because of their size and the planned range of observations. In addition, the very low temperature mechanical cooler required for the Atmospheric Infrared Sounder (AIRS) poses a technical challenge, though we have the option of operating the instrument at a slightly higher temperature with marginally reduced vertical resolution. Almost all of the other proposed EOS instruments have been flown in some form aboard earlier (often shorter) missions or are currently planned for flight.

NASA has identified a core payload of instruments whose flight on EOS-A is critical to the accomplishment of the science objectives of the USGCRP. The science community has stated, and the National Academy of Science review validated, that the flight of this set of instruments is important. Our intent is to take every reasonable step to protect the flight of this payload.

b. We have several contingency plans in the event of development difficulties with one of the EOS-A sensors. Each instrument selected for flight will be required to provide, and have project officials approve, a descoping plan to resolve potential schedule, cost, or technical concerns. If descoping cannot resolve these concerns, then we have the option of shifting the flight of the instrument to the second and third platforms in the EOS-A series. However, the EOS Payload Advisory Panel has stated that it would prefer to slip the launch of the platforms up to a year to protect certain elements of the core payload.

The timeline for development of EOS-A instruments, and the platforms, depends heavily on consistent funding for the program.

c. Because of the critical imaging observations that it would provide, and the critical role such observations play in meeting the science goals of the EOS program, we have determined that we

would not fly the EOS-A platform without the Moderate Resolution Imaging Spectrometer (MODIS).

The EOS Payload Advisory Panel has stated that it would advise a short delay in the launch of the platforms rather than flying without one of the instruments in the core payload. Of the instruments for which development is necessary, the Panel stated that it would be advisable to delay the launch up to a year to wait for the MODIS-Nadir and Clouds and the Earth's Radiant Energy System (CERES) instruments.

Responses to written questions submitted by Chrm. Hall resulting from the October 2, 1990. hearing.

QUESTION 1:

Are there any estimates, either in dollar amounts or percentages, of the U.S. taxpayer's contributions that will be made by our international partners. If not, is there a process in place to report this data?

ANSWER 1:

The Earth Observing System and the near-term missions associated with Mission to Planet Earth include substantial international involvement. While specific estimates of foreign dollar contributions are not currently available, it appears that foreign Earth observation expenditures as a portion of overall space activities is commensurate with the percentage being spent by NASA on such efforts. Examples of these efforts include substantial foreign contributions to the Upper Atmosphere Research Satellite and TOPEX/POSEIDON oceanography mission, along with other efforts such as the Canadian Radarsat program, the European Remote Sensing Satellite (ERS-1), the Japanese Earth Resources Satellite (JERS-1), the Japanese Advanced Earth Observations Satellite (ADEOS) -- on which U.S. instruments will fly -- and planned Indian and Brazilian missions.

The Japanese and Europeans have each planned for development of their own polar orbiting platform series of spacecraft. These platforms represent a significant commitment to global observations. Given this commitment, the EOS partners have coordinated their efforts to provide the broadest possible range of Earth observations. The European and Japanese platforms may also offer the opportunity to fly additional U.S. instruments, such as the Laser Atmospheric Wind Sounder (LAWS), though no specific payload selections have been made. Similarly, individual European and Japanese instrument contributions to the EOS program will depend on the final NASA payload selections for each of the EOS polar orbiting platform series.

QUESTION 2:

Do you feel, at this point in the project, that NASA has made every effort to implement international cooperation? Could you cite specific examples of these efforts?

ANSWER 2:

Yes. The EOS program is one of the most internationally well-coordinated programs in which NASA has ever participated. Since global change research requires worldwide observations and contributions, international involvement has been a cornerstone of planning from the very inception of the EOS program. Such involvement includes participation both by nations with space observation capabilities and by those nations able to contribute in situ observations and data analysis. Working through the CEES and a variety of international scientific and governmental

organizations, NASA has sought and achieved extensive cooperation on the EOS program. An indication of the success of these efforts are the decisions by U.S., Japanese, and European governments to plan for the flight of several polar orbiting spacecraft and the exchange of instruments. Close coordination of these efforts has taken place through groups such as the Earth Observation International Coordination Working Group (EO-ICWG) and the broader Committee on Earth Observations Satellites (CEOS). Science planning has involved a close consultation with the International Geosphere-Biosphere Program (IGBP) and the World Climate Research Program.

International cooperation in the area of data exchange will be critical to the ultimate success of the EOS program. We have made significant progress in involving the international science community in the planning for the EOS Data and Information System (EOSDIS) and the formulation of international Earth science data policies. The Announcement of Opportunity for the EOSDIS solicited input from the entire worldwide user community. The international CEOS Working Group on Data has been active in defining common data formats for user products to facilitate the use of similar data from different satellites. Concurrently, the EO-ICWG has pursued common data policies among the international partners in the polar orbiting platform program. The national members of these groups have made significant efforts to collect input from their various user communities and to reflect varying data needs within the proposed international data policies.

In addition, NASA proposed that Earth science be made a cornerstone of the planning and program effort for the International Space Year (ISY). This international effort has, in turn, led to even greater cooperation on science and data issues and broader involvement by the world community of nations.

QUESTION 3:

Has NASA done any internal studies, or requested external studies, of the accessibility and cost of Landsat data for global change research purposes?

ANSWER 3:

There have been extensive discussions within the Administration concerning the future of the Landsat program. A major concern has been the relatively limited use of Landsat data by Federal and university researchers because of the commercial rates. While the recent National Research Council (NRC) review of the U.S. Global Change Research Program (USGCRP) and the Earth Observing System (EOS) did not specifically include Landsat data as part of its charter, the study did make special note of the problem, stating that "in our view, Landsat data are sufficiently important to global change research that means should be found to include them in EOSDIS [the EOS Data and Information System], whether by revising the Land Remote Sensing Commercialization Act, if necessary, or by paying (again) for the data." NASA agrees with the NRC assessment of the importance of Landsat data as part of the global change data set for long term trend analysis.

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COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES
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COMMITTEE ON GLOBAL CHANGE (202) 334-3511

November 28, 1990

The Honorable Bill Nelson
U.S. House of Representatives
Chairman, Subcommittee on Space Science
and Applications
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Nelson:

Enclosed please find my responses to the additional questions following the October 2 hearing on the Earth Observing System.

I appreciate the opportunity to participate in the hearing and to provide you with additional information.

Sincerely,

John A. Eddy

Enclosure

NOV 29 1990

Responses to Questions Posed to Dr. John A. Eddy by the House Subcommittee on Science and Applications

1.a. The recent NRC report, The U.S. Global Change Research Program: An Assessment of the FY 1991 Plans (referred to below as "the report"), points out that a gap in the continuity of measurements of the Earth's radiation budget will occur in the middle of the 1990s if no additional missions are flown. Such a mission would be suitable for the Earth Probes series. In the near term, other nations are planning to fly missions that will be useful for obtaining these types of measurements. The joint French/Soviet radiation experiment, the Scanner for Radiative Budget (SCARAB), is expected to be launched on two spacecraft in 1991 and 1992. Significant suborbital and ground-based research programs are already underway or are being planned under the international World Climate Research Program and the U.S. Global Change Research Program, as indicated in the report. EOS will make similar measurements, but there will be a gap between, SCARAB and EOS that threatens the continuity of the record, hence its value for identifying trends. Closing the major observational gaps should must be done on a nationally and internationally coordinated basis through the existing relevant programs and on a fully-integrated basis, using space, suborbital, and surface observations.

1.b. The EOS-A platform serves a number of objectives in

addition to collecting data on the role of clouds in climate change. The report notes its authors opinion that if budget constraints arise, it would be more desirable to delay the launch of EOS spacecraft than to forego or diminish the near-term missions that are prerequisite to EOS. If an interim mission to gather radiation data is not flown in the mid-1990s, then delaying EOS would exacerbate the data gap.

2. In the unfortunate event of insufficient near-term funding for these high-priority activities, the report stated in the Summary (p.6) as well as in the body of the text that "...if budget constraints arise, it would be more desirable to delay the launch of the EOS spacecraft than to forego or diminish the effectiveness of near-term missions." Moreover, if any descoping of the EOS mission itself becomes necessary because of budgetary constraints, that should be undertaken in full consultation with the scientific community.

3. I disagree. The report concluded that we now know enough to plan and implement a long-term monitoring program. Certainly, most if not all, of the key variables in environmental change have been at least identified and we need to begin a comprehensive monitoring program at the earliest date possible. Given the long lead times necessary to implement such a program, any further delay at this time would not be prudent. This is not

to say, however, that the scientific community has a full and accurate understanding of all the parameters important to global change, or of their complex interactions. As new knowledge is generated and new discoveries are made, the research strategy and related observational programs will require adjustments. This is why the report emphasized that both the research strategy and the supporting hardware components must be sufficiently flexible to evolve in response to new scientific and technological understanding.

4.a. NASA has stated that the principal reason for a 15-year research mission is "programmatic;" that is, it will take roughly 7-8 years to evaluate the science and technology associated with the program, and another equivalent period to transfer the most important sensor observations to a continuous, "operational" status for long-term monitoring. From a purely scientific standpoint, 15 years is a fairly arbitrary number. Nevertheless, it should be a long enough time period in which to assess the scientific relevance of all the observations in the global change context, and to determine their relative importance for continuation on an operational basis.

4.b. Any answer to this question would be purely speculative and would depend on a broad range of factors both within and outside the program. The report pointed out that continuity of measurements is particularly important and that NASA should

develop contingency plans to ensure continuity (see my response to question 4c).

4.c. The report addressed the issue of data continuity and reliability in some detail (see pp. 64-67). It identified four potential approaches that should be considered to help assure continuity of key measurements: sensor redundancies; "hot spares;" backup data products from sensors with overlapping, but not identical measurement capabilities; and comprehensive interagency and international coordination.

5.a. I am aware of the proposed "Strategic Environmental Research Program," but I am not familiar with the details. It was also not considered by the two panels that wrote the report. I will therefore not comment on questions b and c.

Responses to Questions Posed by Congressman Hall

1. Our panels did not examine alternative management systems for EOS or EOS-DIS, but focussed on the scientific objectives and strategies of current plans. Therefore, I cannot comment.

2. NASA has established a two-tiered data access policy. As

discussed on p. 77 of the report, "users who agree to place the results of their investigations in the open literature will pay only the nominal incremental cost of reproducing and delivering the data requested. In exchange for access at low cost, these users must agree, through the stipulations of a standard "Research Agreement," to make available to the research community the derived data, algorithms, and models at the time of acceptance for publication. Low cost data are to be used only for the researcher's bona fide research purposes. Data may be copied and shared among other researchers provided that they are covered by a Research Agreement or that the researcher who obtained the data is willing to take responsibility for compliance. Commercial users of EOSDIS will be charged market prices through an intermediate vendor." Thus, if a U.S. business were to follow the terms of the standard Research Agreement and share the results of its research on an open basis, it would pay the same price as any other "bona fide researcher."